INSTRUCTION MANUAL

FOR

MODEL 440RF/C

RADIATION EXPOSURE RATE

MEASURING SYSTEM

ION CHAMBER

INSTRUCTION MANUAL

FOR

MODEL 440RF/C

RADIATION EXPOSURE RATE

MEASURING SYSTEM

Part No. 440-399

440RFC680
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USER CAUTION

If this instrument is intended for the detection and measurement of ionizing radiation, it should be used only by persons who have been trained in the proper interpretation of its readings and the appropriate safety procedures to be followed in the presence of radiation. All instructions and warnings contained in this manual or on the instrument must be read before use and must be strictly followed. Failure to follow these instructions and warnings may result in inaccurate readings and/or user hazard. Battery and other operational checks must be performed prior to each use to assure that the instrument is functioning properly.

READ YOUR INSTRUCTION MANUAL

WARRANTY

This instrument and its accessories, excluding those accessories listed below, is warranted by VICTOREEN, INC., against defects in materials and workmanship for a period of one year* from the date of original shipment. During the warranty period, VICTOREEN will repair or, at its option, replace, at no charge, an instrument containing such defect, provided that it is returned, transportation prepaid, to the authorized VICTOREEN repair facility. Instruments repaired in warranty will be returned transportation prepaid within the United States.

*Specific mechanical products may have a more limited warranty period as stated in the front of this manual.

In addition, the calibration of each instrument is warranted to be within its specified accuracy at the time of shipment. If an error in this initial calibration is discovered, the instrument will be recalibrated at no charge, provided it is returned as described above. This does not apply to any calibration deviation that may result from normal use.

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This warranty does not apply if the product, as determined by VICTOREEN, is defective because of normal wear or accident or misuse, or as a result of service or modification by other than an authorized VICTOREEN repair facility. This warranty is void if the unit is subjected to temperatures above 55°C., or contaminated with radioactive material.

This warranty specifically excludes the following items which are covered by their original manufacturers' warranty: photomultiplier, geiger and proportional tubes, crystal and other solid state detectors, batteries and major ancillary items of instrument systems, such as, but not limited to, recorders, printers and display devices.

NON-WARRANTY SERVICE

If repairs or replacement not covered by this warranty are required, a repair estimate will be submitted for approval before proceeding with the repair or replacement.

IMPORTANT: In order to expedite your repair, please supply the following: 1) Complete detailed description of problem, 2) Purchase Date, 3) Name of Vendor, 4) Order Number. Also, indicate which, if any, accessory items (batteries, carrying case, check source, voltage converter, etc.) are included in the return.

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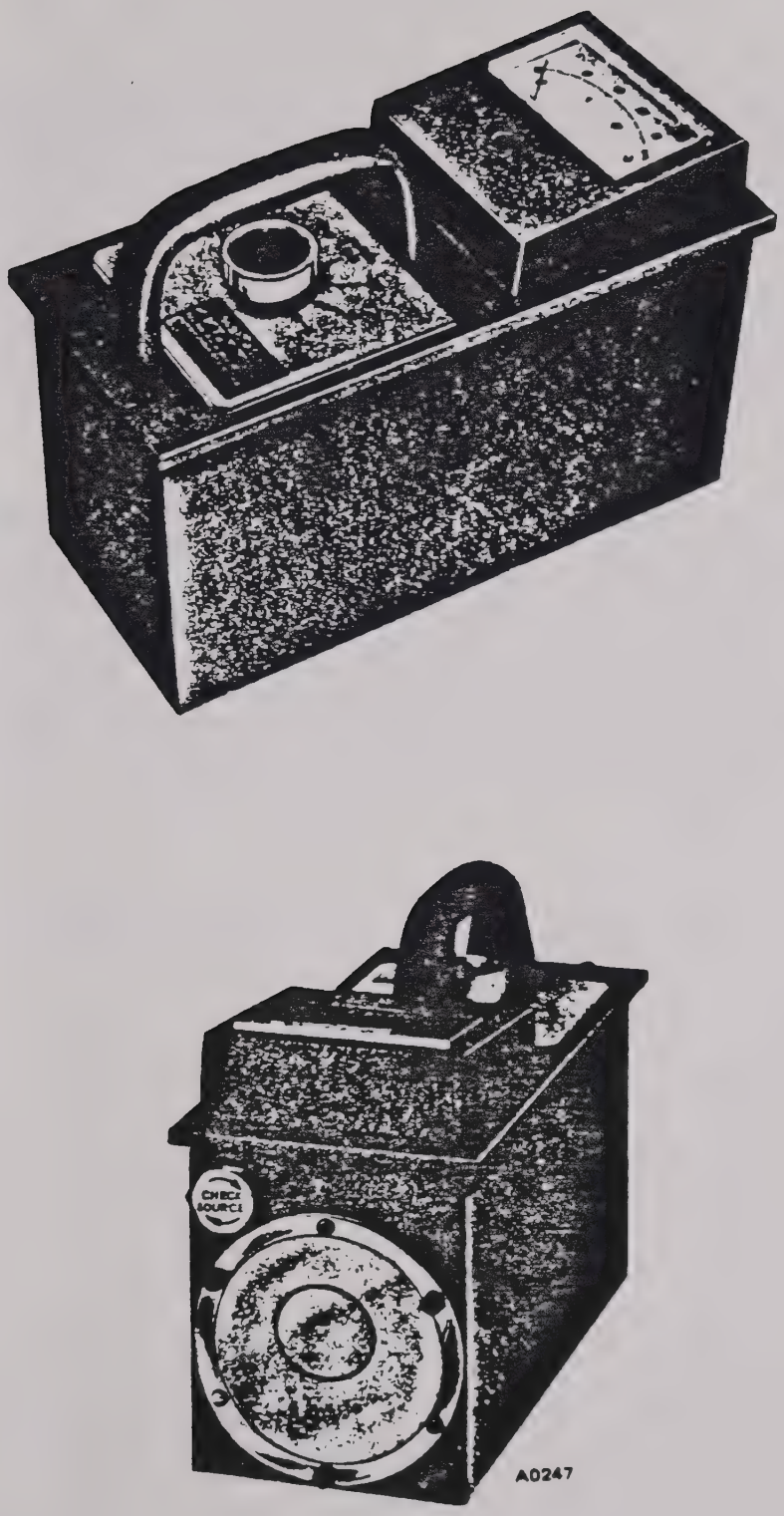


Figure 1. Model 440 RF/C Radiation Exposure Rate Measuring System

1 Purpose - The Model 440 RF/C Radiation Exposure Rate Measuring System has been specifically designed for the measurement of low intensity gamma or X-ray radiation fields. It is also suitable as a beta detector. Response to gamma radiation over the energy range of 6 keV to 1.2 MeV is achievable with field intensities as low as 0.1 mR/hr. The upper limit of measureable exposure rate is 100 mR/hr.

This instrument is valuable for X-ray leakage detection; especially in the vicinity of electronics equipment which may have large electromagnetic (RF) fields associated with it. The 440 RF/C is entirely nonresponsive to such fields and responds only to ionizing radiation.

1.1 Description - The Model 440 RF/C is a portable, RF-shielded, Radiation Exposure Rate Measuring System. The instrument consists of a radiation detector (or transducer) and electronic amplifying and metering means. The radiation detector is a guarded, unsealed, air ionization chamber. The extremely small d.c. current produced by the ion chamber is monitored by means of a dynamic capacitor electrometer system which is connected as a true operational current-amplifier using a high megohm feedback resistor. All amplification is a.c. coupled and gain stabilized. The d.c. signal recovery is performed by a low noise, phase-sensitive synchronous rectifier. All supply voltages are regulated.

1.2 Specifications - Specifications for the 440 RF/C are listed in Table I.

TABLE I: SPECIFICATIONS FOR THE MODEL 440RF/C

Feature	Specification
Full Scale Ranges	0-1, 0-3, 0-10, 0-30 and 0-100 mR/hr
Radiation Detected	Gamma, X-ray and Beta
X and Gamma Energy Response	±10% from 12.5 keV to 42 keV effective; with a maximum response peak of +40% in the medium energy range
Beta Response	Energies above .15 MeV
RF Insensitivity	Operates properly in 10 mW/cm^2 fields
Magnetic Insensitivity	Operates properly in a 200 gauss field
Accuracy	Maximum instrument inaccuracy, exclusive of energy dependence, is less than ± 10% of full scale indication
Response Time	Standard, approximately 12 seconds from 0 to 90% of scale. Optional, approximately 7 seconds from 0 to 90% of scale
Ion Chamber:	
Chamber Window Area	10 cm^2
Volume	60 cc
Dimensions	2.5 in. length, 1.5 in. diameter
Chamber Window	Approximately 1 mg/cm^2 Aluminized Mylar
Case Window	13 mg/cm^2 Magnesium
Battery Complement	Four D size cells (NEDA Type 13; One 22-1/2 volt Eveready No. 412
Battery Life	NEDA Type 13; 100 hours at 4 hours per day. Eveready No. 412; shelf life as specified by manufacturer
Net Weight	8.5 lb
Overall Dimensions	10-7/8 in. long, 4-7/8 in wide, 8 in. high including handle

2 General

2.1 Turn-On Battery Check and Range Changing - A single rotary switch, located beneath the carrying handle is employed to perform all function and range changes. In the maximum counter-clockwise position, OFF, the battery power supply is disconnected. In the interest of battery life and the possibility of battery compartment damage, due to leaking, or

spent cells, the switch should be returned to this position whenever the instrument is not in use. Any other switch position will cause full battery drain current.

When first operating the instrument, after a period of idleness, switch into, and remain in, the BAT position. This position's function is to monitor the condition of the D cell battery. This is accomplished by metering the regulated +4.0 volt d.c. buss. This indication will not change until the regulator no longer has sufficient battery voltage to work from. The meter needle should indicate in the black zone of the meter arc, from .0. to full scale. If the indication ever drops beneath this zone, the D cells should be all replaced at once.

Assuming the battery check is performed successfully, the function switch may now be rotated to the first exposure rate range 100 mR/hr. If the instrument has just been turned on, there may be an up-scale indication on this range, but it should be a rapidly decaying one. When the indication on this range is, or has decayed to, less that one-third of full-scale, switch to the next clockwise position (the 30 mR/hr range). Continue in this way until either a steady indication greater than one-third of fullscale, or the most sensitive range is reached. If the instrument has not been used for some time, this procedure may take a few minutes.

If the instrument is brought closer to a source of radiation, or a radiation source is intensified such that greater than fullscale is indicated, the range switch can be rotated counter-clockwise to less sensitive positions. For purposes of accuracy, always set the range switch such as to give the maximum on-scale indication.

2.2 Instrument Positioning and Scanning - Generally, after warm-up and range selection, the measuring system is placed in some specific location and attitude and a reading obtained. Operator knowledge of radiation source locations, special geometry applications, physical placement problems, etc., all affect exactly where and how the instrument is positioned. Because the instrument's low-energy response is best for photons which enter the case through the magnesium window, the operator should try to keep the magnesium window facing in the direction of increasing intensity, i.e., toward the source.

It should be emphasized that the instrument responds to the effective exposure rate averaged throughout its ion chamber volume. The exposure rate 10 or 100 centimeters away cannot be predicted without a rather complete knowledge of the shape, direction, and contours of the radiation fields involved. If this concept of measuring a very local field, rather than a general area, is borne in mind much confusion is dissipated.

Operator knowledge regarding the location of radiation sources can be divided into several classifications. Each classification demands its own special approach.

2.2.1 Precise Location - Obviously, little or no difficulty will be encountered in positioning the instrument for either a nominal indication at a fixed location or a maximized indication with only a small amount of positioning.

2.2.2 General Vicinity - Some small amount of careful scanning, less than a few square feet, can be employed without fatigue or the possibility of missing a small indication. See Figure 2. Maximum scan-line speed should be between 2 and 4 feet/minute depending on how low in intensity a source may be encountered. The scanning motion should be slow, smooth and uniform. If any upscale indication occurs, the scan should be stopped immediately, in order to determine whether the instrument detected only a random cosmic ray or a tiny intense beam.

N O T E

The scanning should be performed with a minimum of jostling or jarring of the instrument particularly when a low exposure rate survey is underway.

2.2.3 No Specific Location - Scanning of large areas at low exposure rates is not recommended for this instrument.

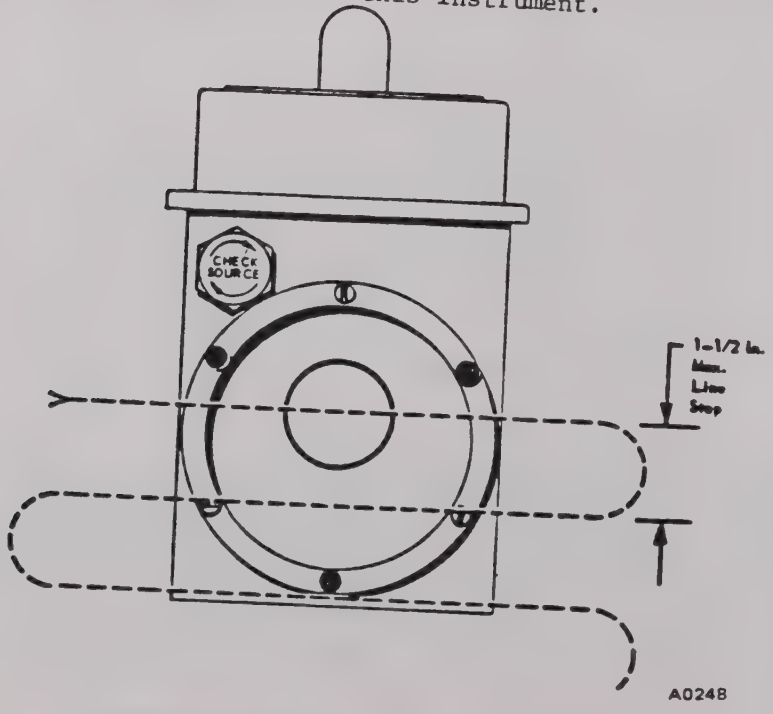


Figure 2. Small Area Scan Technique

2.3 Chamber Location - Because the ion chamber is not normally visible, some information on the actual location within the case, in terms of outside markings and dimensions, will be helpful in precision or special geometry applications.

The ion chamber is in the form of a right cylinder. It is located at the panel meter end of the case with its axis parallel to the longest dimension of the case. For exact dimensions, see Figure 3.

Three plastic bumpers are arranged in a triangle on the outside mounting ring of the magnesium window. Their tops define a plane. This plane will also be any flat surface that all of the bumpers contact. The mid-plane (the ion chamber's mid-plane is defined as: that plane, at right angles to the axis, which separates the total effective volume of the chamber into two equal volumes) of the ion chamber is exactly 5 cm deep in the case from this plane.

A black ring, 1-1/2 inches diameter, is silk-screened on the outside surface of the magnesium window. It serves as a quick guide to the ion chamber's size and location.

The chamber's aluminized-myler end-window is parallel to, congruent with, and directly behind the black ring screened on the magnesium window.

2.4 Measurement of Exposure Rate

2.4.1 Unit of Measurement - The Model 440 RF/C is used to measure ionizing radiation in terms of exposure rate, whose unit is the roentgen per time unit.

An exposure rate of one Roentgen per time unit is that intensity of X or gamma* radiation which produces ion pairs amounting to one Electrostatic Unit of charge in each cubic centimeter of standard conditions air per time unit.

This instrument indicates in milliRoentgens per hour mR/hr, that is, thousandths of a Roentgen per hour.

Any ionization chamber used to determine Exposure Rate, as defined above, has a number of characteristics implied:

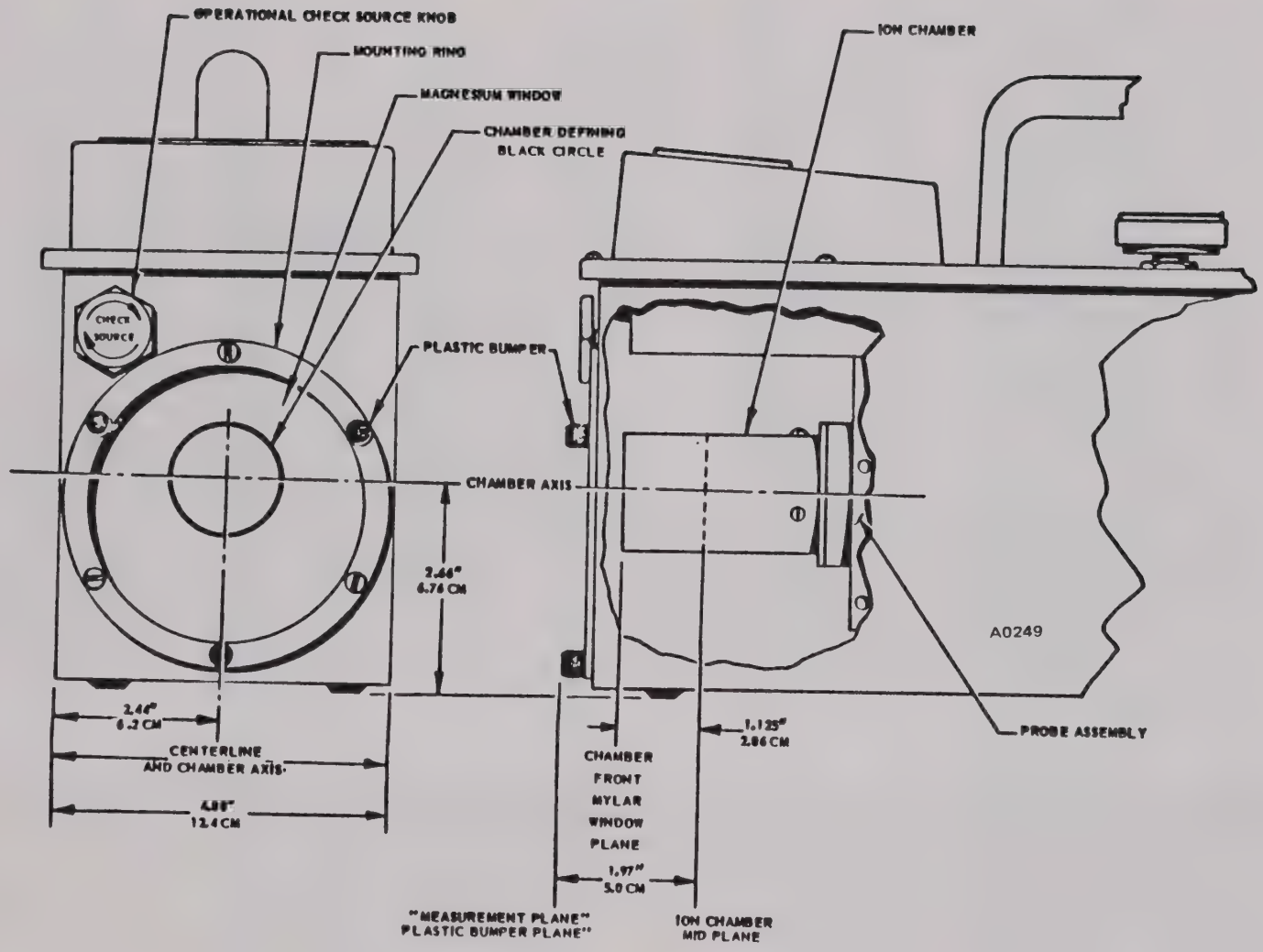


Figure 3. Chamber Reference Dimensions

1. Total collection of all ion pairs created.
2. Relative independence of ion pair generation on the energy of the photons.
3. The intensity of the radiation remains constant throughout the air volume.

In many real measurement situations some of these conditions will be difficult or impossible to meet. We will then need a correction factor to more closely approach a true value.

2.4.2 Obtaining Readings From Indications - Although there is a special section devoted in this manual to low-level measurements, Section 2.7, the instructions given here apply generally to both high and low-level measurements.

2.4.2.1 Response Time - The measuring system requires a certain amount of time to respond to a change in exposure rate. The response time as given in Section 1.2 is the time required to reach 90% of the final new value. This means there is still a 10% error, due to response time, remaining. If twice the quoted response time is allowed, the time error will fall to less than 1%. In all measurements, therefore, proper time must be allowed before obtaining a reading from an indication.

---

*Exposure rate is not really defined for beta particle radiation. Any indications should be only as indications of relative beta particle intensity and not as indications of exposure rate, (or milliRoentgen per hour).

2.4.2.2 Meter Arcs and Range Positions Correspondence - The 0-10 meter arc contains 10 major and 50 minor divisions and corresponds to the 0-1, 0-10 and 0-100 mR/hr range positions.

The 0-3 meter arc contains 6 major and 30 minor divisions and corresponds to the 0-3 and 0-30 mR/hr range positions.

2.4.2.3 Reading the indication - No difficulties should be experienced in setting the decimal point and making interpolations. For example:

Range Position: 100 mR/hr.

Indication (On "0-10" Meter-Arc): Four (4) major divisions plus two and one-half (2-1/2) minor divisions.

	Major Divisions		Minor Divisions		
Reading:	$\frac{4}{10}$	+	$\frac{2.5}{50}$		
	$\frac{40}{100}$	+	$\frac{5}{100}$	=	$\frac{45}{100}$
	$\frac{45}{100}$	x	100 mR = 45 mR/hr.		

Figure 4. Reading Meter Scale Indications

2.4.3 Applying Corrections to Readings - After a reading has been obtained, the operator should be able to ascertain whether or not any correction factors, such as those covered in Sections 2.5 and 2.6 apply. If no correction factors apply, or only a relative indication is desired, the readings can be taken as final data. If there are correction factors that apply and accuracy is required, then they must be applied before readings can be considered as final data.

Correction factors are numbers, ranging around unity in value, which are multiplied with the reading to give a corrected reading. They correct for errors contained in the initial reading due to some non-ideal or non-standard condition of the measurement.

2.4.3.1 Necessity of Applying Corrections - Corrections are not required where a maximum inaccuracy of 25 to 30% can be tolerated, as during a casual survey. However, when the highest possible accuracy is desired, all likely sources of inaccuracy should be considered, and corrections and compensations applied where necessary.

2.4.4 Arbitrary Standards - Government and/or industrial agencies may not adopt a standardized measurement or set of conditions for same. When this is done, it is helpful to know which correction factors might apply and which would not. Generally, when a certain detector cross-sectional area and external surface to center of effective volume spacing is specified, the geometry factors are fixed and correction factors relating to geometry (Section 2.5) are not used. Energy and air-density corrections, Sections 2.6.1 and 2.6.2, however, would still apply for maximum accuracy.

2.5 Source Geometry Corrections

2.5.1 Proximate Source - In the exposure rate definition, Section 2.4.1, the necessity for either a constant intensity of radiation throughout the chamber volume or a suitable correction factor can be seen. Since ionizing radiation follows the inverse square law, the same as visible light, radio-waves, etc., only at distances several times the maximum dimensions of the chamber is the field relatively constant throughout the chamber. In Figure 5, a calculated correction curve is given for point sources of radiation that closely approach the chamber.

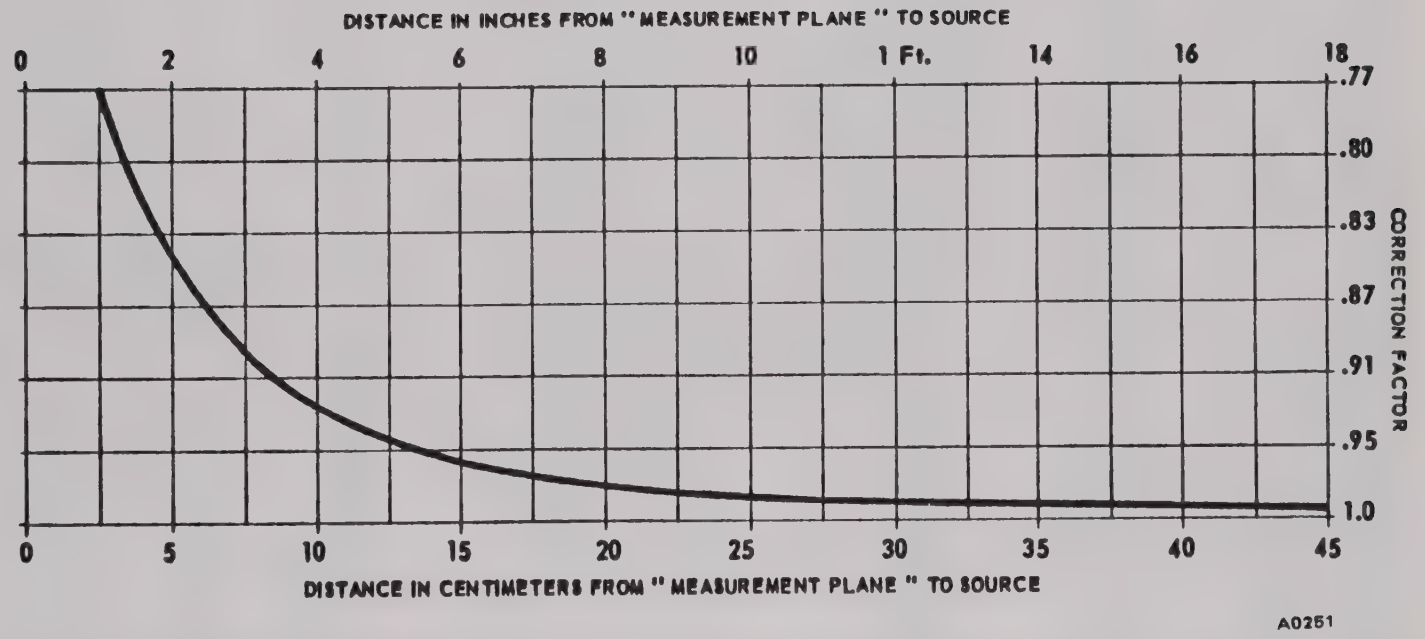


Figure 5. Proximate Source Correction Curve (Calculated)

2.5.2 Small Cross-Section Beam - As in Section 2.5.1, constant radiation intensity throughout the chamber volume or a correction factor is required. This is the only practical way a chamber can be calibrated. If a small cross-section beam, see Figure 6, ionized only a fraction of the chamber volume, the resultant indication will reflect an overall averaged value rather than the beam cross-section value. In order to correct for this kind of error, the actual cross-sectional area of the beam must be shown.

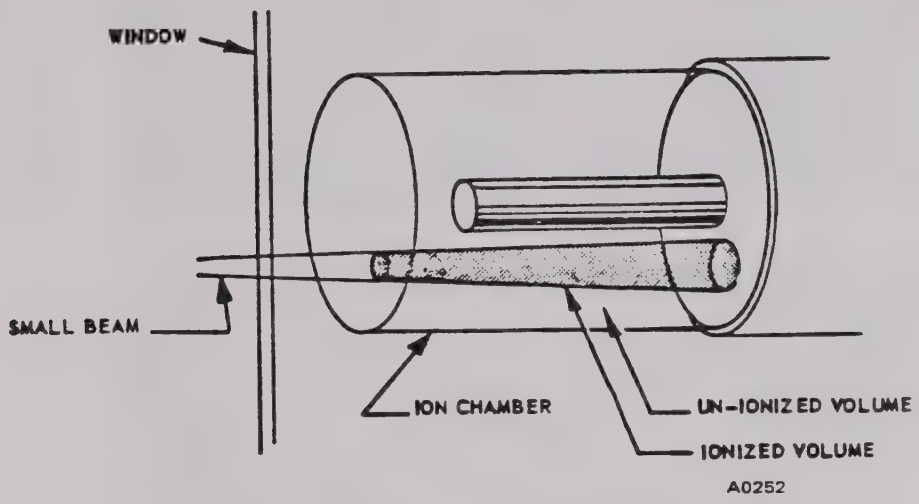


Figure 6. Small Cross-Section Beam

The Model 440 RF/C cannot be used to accurately determine beam cross-sections. One possibility is the use of photographic sheet film. If the cross-section is well defined (rather than diffuse) on the film, then the cross-sectional area can be scaled off. This will then allow the computation of a rough correction factor. For example:

$$\text{Small Cross-Section Beam Correction Factor} = \frac{\text{Cross-Sectional Area of Chamber}}{\text{Total Cross-Sectional Area of Beams}} = \frac{10 \text{ sq.cm.}}{X}$$

Most beams found associated with color television receivers are on the order of 1 sq. cm cross-sectional area, or larger.

2.5.3 Skew Beams - Just as the cross-sectional areas of X-ray beams vary, so does the three dimensional angle, at which it leaves the apparatus in which it was generated.

Normally the Exposure Rate Measuring System is positioned with its magnesium window parallel to the external surface of the apparatus being surveyed. This places the ion chamber axis parallel to any beams that leave the apparatus normal, or at right angles, to the surface. It is likely that some beams will not follow this pattern. If the angle is small with respect to the normal, little or no error occurs. Also if the beam has a large cross-section (compared to the chamber) the error is slight. But for small cross-sectional area beams at large angles from the normal, the error could be large (see Figure 7). The Model 440 RF/C can be tipped off of the normal axis in the direction and angle which yields the maximum indication. This then will reduce the problem to the small cross-section problem.

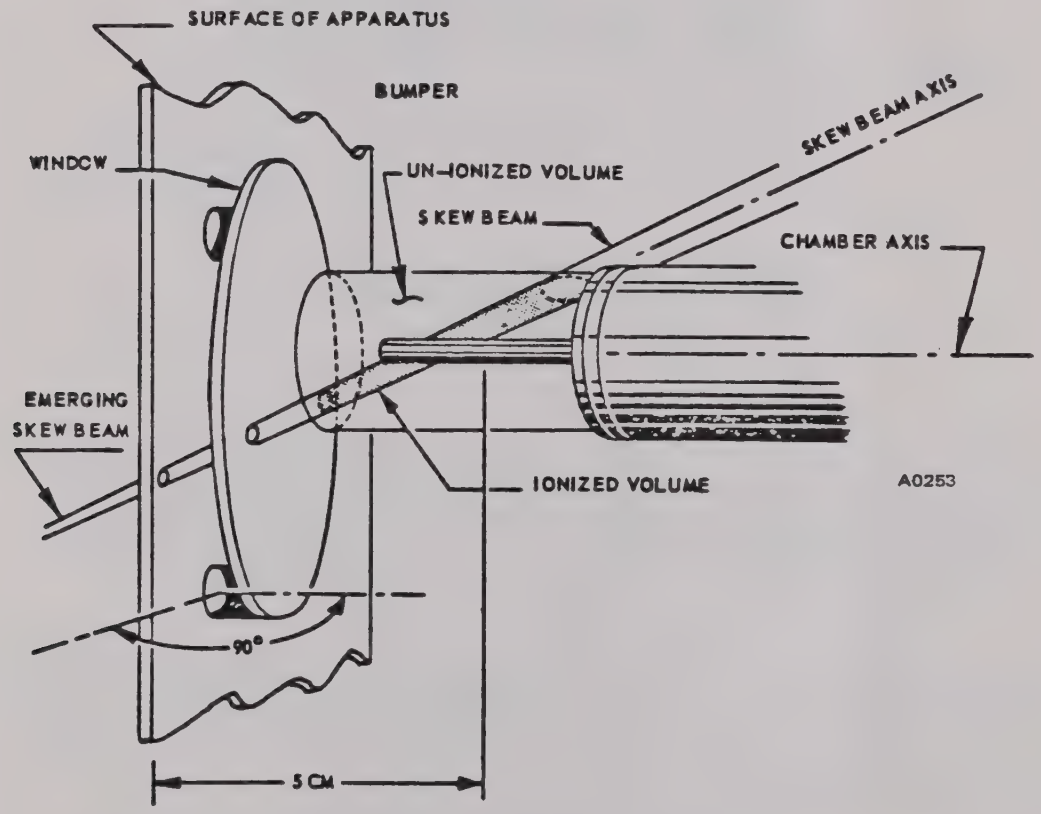


Figure 7. Skew Beam

2.5.4 Plane Source - A plane source of radiation presents a unique measurement situation. A color television picture tube faceplate can be treated for all practical purposes as a plane source, because of the speed of scan and frame rate. The bulk of X-ray photons are generated when the electron beam strikes the shadow mask. The thick glass faceplate acts like a low-energy filter or absorber. In Figure 8, the geometries of the tube and measurement system are shown. The most important characteristic of a plane source is that it tries to illuminate the chamber volume from a large oblique angle. This makes instrument centering meaningless. At higher energies the case and chamber wall are about as transparent to photons as the magnesium and mylar windows. But, in the energy range expectable of a color television receiver, this is not the situation; and some oblique angle contribution is lost in the case wall. Matters are helped somewhat by the increased absorption for oblique angle photons since they have a longer path to travel in the glass faceplate. This tends to reduce the error.

At an applied constant potential of 35 kV on a color kinescope, comparisons were made between the Model 440 RF/C and a low-energy spherical geometry chamber (Model 415C). Presuming complete oblique contribution in the spherical chamber, the correction factor for the Model 440RF/C was 1.2. For other energies (accelerating voltages) and different kinescopes the correction factor may well be different.

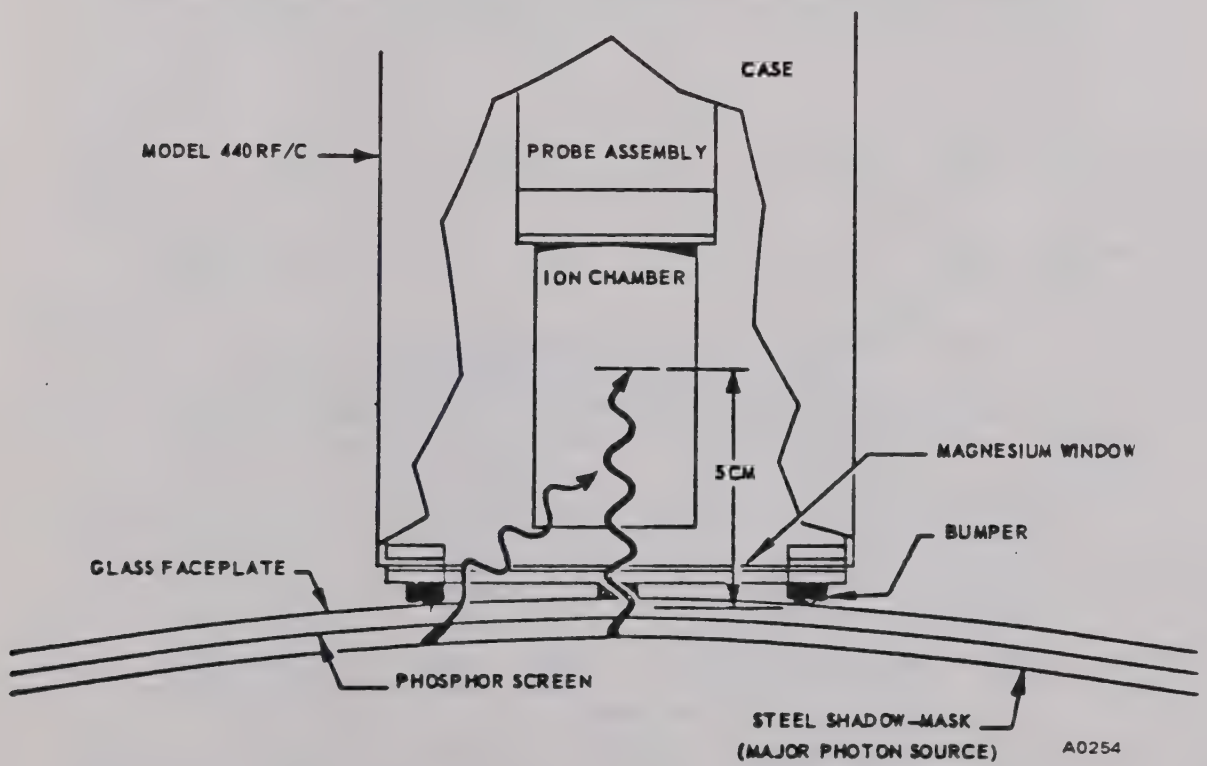


Figure 8. Plane Source (Color TV Screen)

2.6 Chamber Corrections

2.6.1 Energy Dependence - Our definition of exposure rate in Section 2.4.1, did not make reference to any specific photon energy. Any ion chamber has a certain energy dependence. That is, holding the exposure rate constant, the chamber responds differently to different energy photons. The Model 440 RF/C has been calibrated at an effective energy of 22 keV. The response is fairly energy independent in the low-energy region. For accurate useage at middle and high energy regions, the Energy Response Correction Curve must be used (Figure 9).

For example, a monochromatic source of X-rays known to have an effective energy of 100 keV indicates as 42 mR/hr on the Model 440 RF/C. In Figure 9, we see that a correction factor of about 0.67 is required. This will convert the reading to 28.1 mR/hr.

Additional Equilibrium Wall Material

For effective energies above 250 keV, additional equilibrium wall material should be used. For the Energy Response Correction Curve, Figure 9, a 1/4 inch thick plastic* plate was used, placed directly in front of the magnesium window and of the same approximate area of the window.

*Any plastic may be used; it is not critical.

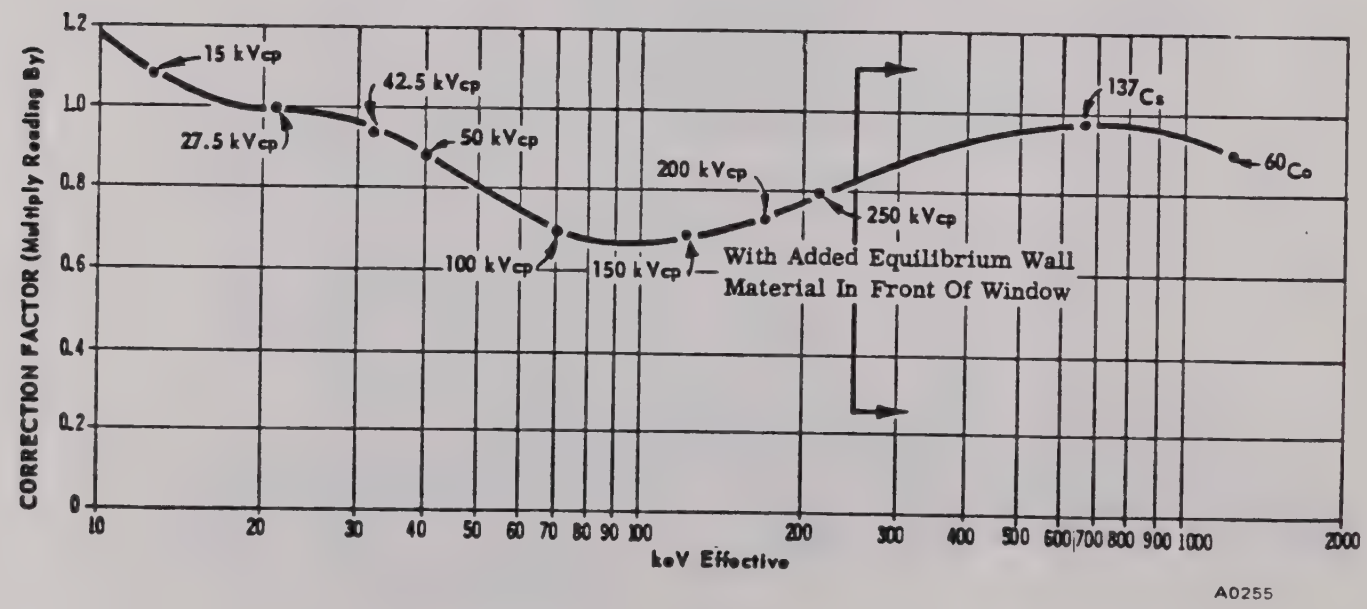


Figure 9. 440 RF/C Energy Response Correction Curve

2.6.2 Temperature and Pressure - Air, at standard temperature and pressure, is the ionized medium in our exposure rate definition. The density of the air determines directly the ionization rate, all other factors held constant. The density is, in turn, a function of barometric pressure and Kelvin temperature. Since the ion chamber is not sealed, correction must be made for temperatures and barometric pressures different from those during calibration.

Standard Temperature, 0^{0}C, is rarely encountered in practice. The Model 440 RF/C is calibrated and corrected to 22^{0}C and 760 mmHg. For different temperatures and pressures, correction factors will be found on the Air Density Correction Table, Figure 10. For example, the temperature and pressure, at a certain location, are found to be 26^{0}C and 745 mmHg at the time exposure rate measurements are made. Using the Table in Figure 10, the correction factor is 1.034.

2.7 Low Level Measurements

2.7.1 Non-Zero and Fluctuating Indications - Without any external radiation and the instrument set on the 1 mR/hr and 3 mR/hr ranges, there is neither a steady nor zero indication, but rather a continuously fluctuating indication, slightly up-scale from zero. This is punctuated occasionally by needle kicks up to about 1/2 mR/hr, and followed by a slower decay back to the zero region. This is normal and to be expected in an instrument of this sensitivity and response time. The various indications on these ranges are attributable to three general origins.

2.7.1.1 External Radiation Background - Even in the absence of any artificial external radiation field, there will always be an external field due to building materials, which contain minute amounts of naturally occuring radioactive elements and cosmic radiation. Together these sources are termed background. Over any short space of time they are statistical or noisy because of the very small activities involved. The averaged value of background ranges between .01 and 0.1 mR/hr depending upon location. Because the instrument has no way of differentiating between background and any other low intensity source, it must be indicated.

2.7.1.2 Internal Radiation - There is a very small, less than .01 mR/hr, contribution due to trace amounts of radioactivity in the chamber materials and residual scatter from the Operational Check Source.

This instrument is calibrated in International Roentgens corrected to 0° Centigrade when used at 22° Centigrade and 760 mm. mercury (Hg) barometric pressure. For temperatures other than 22° Centigrade and pressures other than 760 mm. Hg., multiply the scale reading by the factor obtained from the following table.

Inches	Mm.	F. 60.8 C. 16	64.4 18	68.0 20	71.6 22	75.2 24	78.8 26	82.4 28	86.0 30	89.6 32	93.2 34	96.8 36	100.4 38	104.0 40
19.68	500	1.489	1.499	1.509	1.520	1.530	1.541	1.551	1.561	1.571	1.582	1.592	1.602	1.613
20.08	510	1.460	1.469	1.479	1.490	1.499	1.510	1.520	1.530	1.540	1.551	1.561	1.571	1.581
20.47	520	1.431	1.441	1.451	1.461	1.471	1.481	1.491	1.500	1.510	1.520	1.530	1.540	1.550
20.87	530	1.405	1.414	1.424	1.434	1.444	1.453	1.463	1.473	1.482	1.492	1.502	1.512	1.521
21.26	540	1.378	1.388	1.397	1.407	1.416	1.426	1.435	1.445	1.454	1.464	1.474	1.483	1.493
21.65	550	1.354	1.363	1.373	1.382	1.391	1.401	1.410	1.419	1.429	1.438	1.448	1.457	1.466
22.05	560	1.329	1.338	1.348	1.357	1.366	1.375	1.384	1.394	1.403	1.412	1.421	1.431	1.439
22.44	570	1.306	1.315	1.324	1.333	1.342	1.351	1.360	1.369	1.378	1.387	1.396	1.405	1.414
22.83	580	1.283	1.292	1.301	1.310	1.319	1.328	1.337	1.345	1.354	1.363	1.372	1.381	1.389
23.23	590	1.262	1.270	1.279	1.288	1.297	1.305	1.314	1.323	1.331	1.340	1.349	1.358	1.366
23.62	600	1.241	1.249	1.258	1.267	1.275	1.284	1.293	1.301	1.309	1.318	1.327	1.336	1.344
24.02	610	1.220	1.229	1.237	1.246	1.254	1.263	1.271	1.279	1.288	1.297	1.305	1.314	1.322
24.41	620	1.200	1.208	1.217	1.225	1.233	1.242	1.249	1.258	1.266	1.275	1.283	1.292	1.299
24.80	630	1.181	1.189	1.198	1.206	1.214	1.222	1.230	1.239	1.247	1.255	1.263	1.271	1.279
25.20	640	1.164	1.171	1.180	1.188	1.196	1.204	1.212	1.220	1.228	1.236	1.244	1.252	1.260
25.59	650	1.145	1.153	1.161	1.169	1.177	1.185	1.193	1.201	1.208	1.216	1.224	1.232	1.240
25.98	660	1.127	1.135	1.143	1.151	1.159	1.167	1.174	1.182	1.189	1.198	1.206	1.213	1.221
26.38	670	1.111	1.119	1.126	1.134	1.142	1.149	1.157	1.165	1.172	1.180	1.188	1.195	1.203
26.77	680	1.095	1.103	1.110	1.118	1.125	1.133	1.141	1.148	1.156	1.163	1.171	1.179	1.186
27.16	690	1.078	1.086	1.093	1.101	1.108	1.116	1.123	1.131	1.138	1.146	1.153	1.161	1.168
27.56	700	1.064	1.071	1.079	1.086	1.093	1.101	1.108	1.115	1.123	1.130	1.137	1.145	1.152
27.95	710	1.048	1.055	1.063	1.070	1.077	1.084	1.092	1.098	1.106	1.113	1.121	1.128	1.135
28.35	720	1.033	1.041	1.048	1.055	1.062	1.069	1.076	1.083	1.091	1.098	1.105	1.112	1.119
28.54	725	1.027	1.034	1.041	1.048	1.055	1.062	1.069	1.076	1.083	1.091	1.098	1.105	1.112
28.74	730	1.019	1.027	1.034	1.341	1.048	1.055	1.062	1.069	1.076	1.083	1.090	1.097	1.105
28.94	735	1.013	1.019	1.027	1.034	1.041	1.048	1.055	1.062	1.069	1.076	1.083	1.090	1.097
29.13	740	1.006	1.013	1.020	1.027	1.034	1.041	1.048	1.055	1.062	1.069	1.075	1.083	1.089
29.33	745	.999	1.006	1.013	1.020	1.027	1.034	1.040	1.048	1.054	1.061	1.068	1.075	1.082
29.53	750	.992	.999	1.006	1.013	1.020	1.027	1.033	1.040.	1.047	1.054	1.061	1.068	1.075
29.72	755	.986	.993	1.000	1.007	1.014	1.021	1.027	1.034	1.041	1.048	1.055	1.062	1.068
29.92	760	.980	.986	.993	1.000	1.007	1.014	1.020	1.027	1.034	1.041	1.047	1.054	1.061
30.12	765	.972	.979	.986	.993	.999	1.006	1.013	1.020	1.026	1.033	1.040	1.047	1.054
30.31	770	.967	.973	.980	.987	.994	1.000	1.007	1.014	1.020	1.027	1.034	1.041	1.047
30.51	775	.961	.968	.974	.981	.987	.994	1.001	1.007	1.014	1.021	1.027	1.034	1.041
30.71	780	.954	.961	.967	.974	.980	.987	.994	1.000	1.007	1.014	1.020	1.027	1.033
30.90	785	.948	.955	.961	.968	.974	.981	.988	.994	1.001	1.007	1.014	1.021	1.027
31.10	790	.942	.949	.955	.962	.968	.975	.981	.988	.994	1.001	1.008	1.014	1.021

A0256

Figure 10. Air Density Correction Table

2.7.1.3 Amplifier Noise - Current noise originating in the high-megohm resistor comprises the major source of fluctuations on the bottom ranges. It has been reduced to as low a value as possible, and the band width of the system has been adjusted for the best compromise between noise amplitude and response time. Although the average value of these fluctuations is zero, they do mask the average indicated radiation level enough that procedures stated in Section 2.7.2 should be employed for precise low-level measurements.

2.7.1.4 Insulator Strain Charges - After rough handling or during transportation, the insulators in the probe assembly of the instrument may have developed strain charges on their surfaces. The only cure is to rest the instrument until the charges bleed off. If the strain charges are up-scale and relatively steady, a measurement can be made and a non-zero compensation applied (see Section 2.7.3).

The best prevantative procedure is to subject the instrument to as little shock, vibration, and abrupt motions as possible.

2.7.1.5 Statistics of Radiation - It will be also found that one limitation in measuring low-level sources of radiation to any high degree of accuracy, in any short period of time, are the statistics of the source. Statistics refer to the notion that there is a lower level of radiation flux per unit of time intercepted by the chamber volume that beneath which the flux measures progressively less a smooth flow and more a series of individual photons.

This effect can be easily observed when measuring the exposure rate of radiation sources on the 1 mR/hr range. The indication will have greater fluctuations, for instance, at 0.8 mR/hr than when only background is present. The amount of electrical filtration or signal averaging employed is a compromise between small fluctuations and long response times.

2.7.2 Obtaining Readings from Fluctuating Indications - In order to differentiate background, the operational check source and low intensity, external radiation from the slightly fluctuating display on the 1 mR/hr and 3 mR/hr ranges; some repeatable and non-ambiguous method of evaluating the fluctuations should be employed. The following method yields as good an average value as any other technique.

While studying the fluctuations for approximately half a minute, try to pick out an upper and lower limit that most (80%) fluctuations remain within. Mentally note or record these limits. See Figure 11.

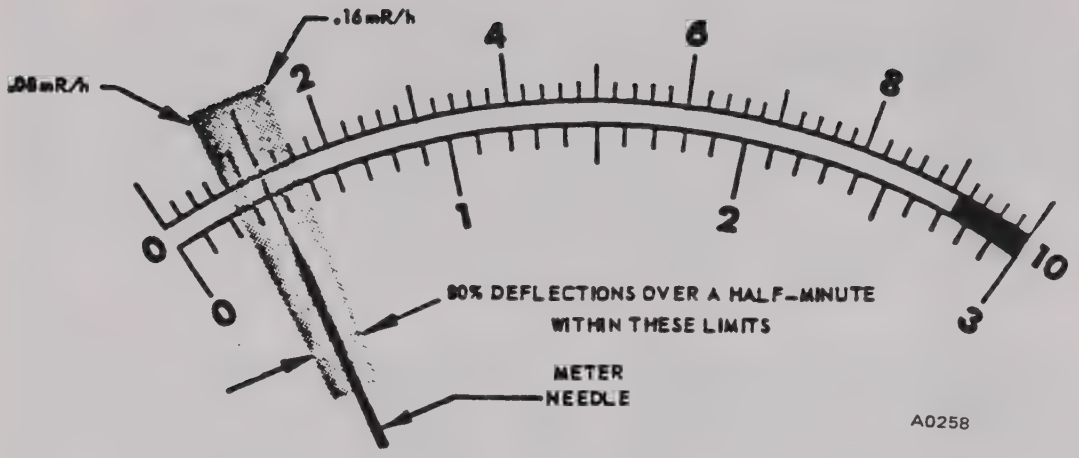


Figure 11. Interpreting Fluctuations

N O T E

On positive (up-scale) indications, disregard occasional (5 to 30/hr) large kicks and decays. These are believed to be either cosmic rays or chamber alphas.

Take the arithmetic mean, by adding the two values and dividing by two.

For example, in Figure 11, a portion of the meter scale is shown and a certain fluctuating indication is represented.

Upper limit . . . . . 0.16 mR/hr
Lower limit . . . . . .+0.08 mR/hr

$$\frac{0.24 \text{ mR/hr}}{2} = 0.12 \text{ mR/hr Average}$$

2.7.3 Non-Zero Compensations - In the event that the local background radiation becomes, or is, an objectionable percentage of the indicated value, it should be simply subtracted out for maximum accuracy at low intensities.

The value used for background can be determined by means stated in Section 2.7.2, as well as of the external radiation or operational check source.

The value used for background should be regularly measured, as there can be short term variations and possible strain charges included in the readings.

For Example:

Indicated and averaged reading	0.80 mR/hr
Less indicated and averaged background reading .	- .03 mR/hr
Compensated reading	0.77 mR/hr

2.8 Operational Check Source - This built-in source enables the operator to verify operational status. A hexagonal knob is located on the front surface of the case bottom, above and to one side of the magnesium window (See Figure 3).

To operate the check source, rotate the knob clockwise (facing knob) until a mechanical stop is reached. This is the calibrated position. Supply enough torque to the knob so that the return spring does not bring the knob off of the end stop during the check procedure.

To halt check source operation, simply remove torque from the knob; the return spring will retract the source back into a shielded position.

When using the check source be sure to allow enough time for a final value to be indicated. This will be about 30 seconds.

N O T E

Use of the Operational Check Source constitutes a low level measurement, and all the remarks of Section 2.7, with regard to interpreting and evaluating fluctuations and background in the indication, apply.

There is a variation in activity from one check source to another. The nominal reading is 1.4 mR/hr, but a range of from 1.2 to 1.5 mR/hr will be found. The exact value for a specific instrument will be found stamped on a special tag cemented just above the nameplate, at the opposite end of the case bottom.

Due to extremely long half-life of the check source material, there will be no measureable decay in source activity over the life-expectancy of the instrument.

3 General Theory - When the ion chamber is exposed to radiation its internal air volume becomes ionized. A d.c. potential applied between the outer shell and center electrode separates the newly-formed ion pairs, before they can recombine, and collects them. The ions upon reaching the electrodes, are restored to neutral gas atoms, through the process of taking on (or giving up) electrons. This causes a d.c. current flow in the external circuit. The ion chamber can be considered a constant current generator whose output current is directly proportional to the rate of internal air ionization or exposure rate. These currents are extremely small, however, and special electrometer circuitry is required to measure them.

An operational, current-amplifier configuration is employed in this instrument. See Figure 12. The large amount of negative feedback causes the output voltage to be a function of input current and feedback resistor value, rather than amplifier gain, or other variables. A dynamic capacitor (vibrating reed) electrometer is used for the operational amplifier. The feedback resistor is a stable, high megohm resistor. Precision film resistors, selected by the range switch, determine the amount of d.c. voltage gain, and hence the fullscale sensitivities of the instrument. A variable resistor is employed to calibrate accurately the meter deflection to a known exposure rate radiation field. A more detailed block diagram is given in Figure 13.

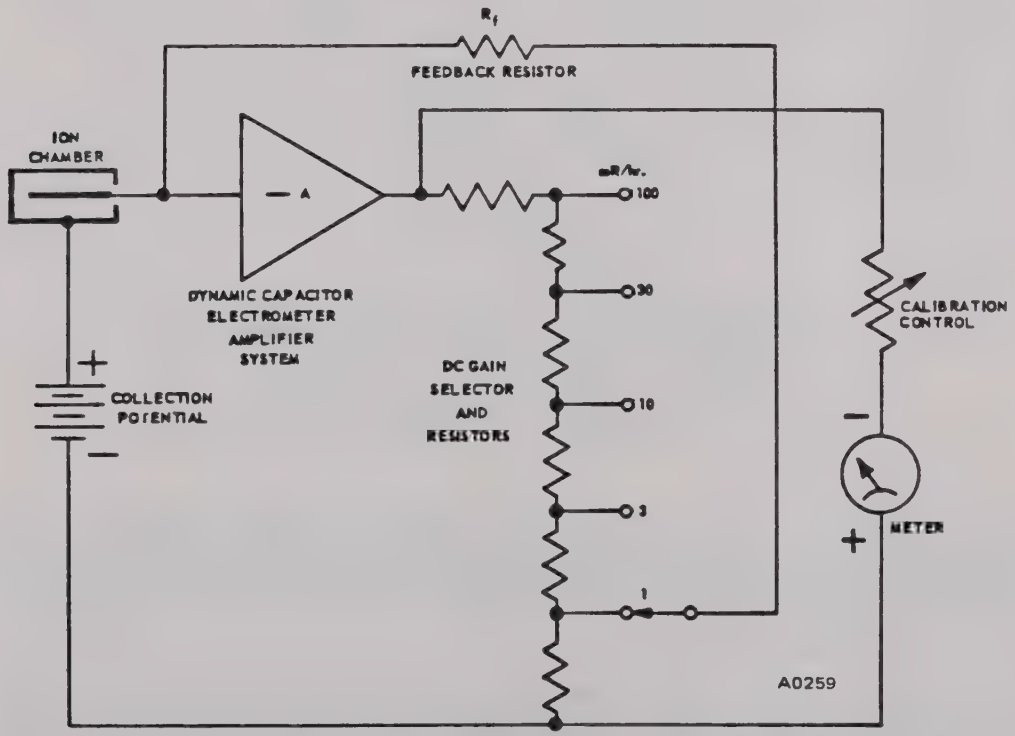


Figure 12. Operational Amplifier; Current-Amplifier Configuration

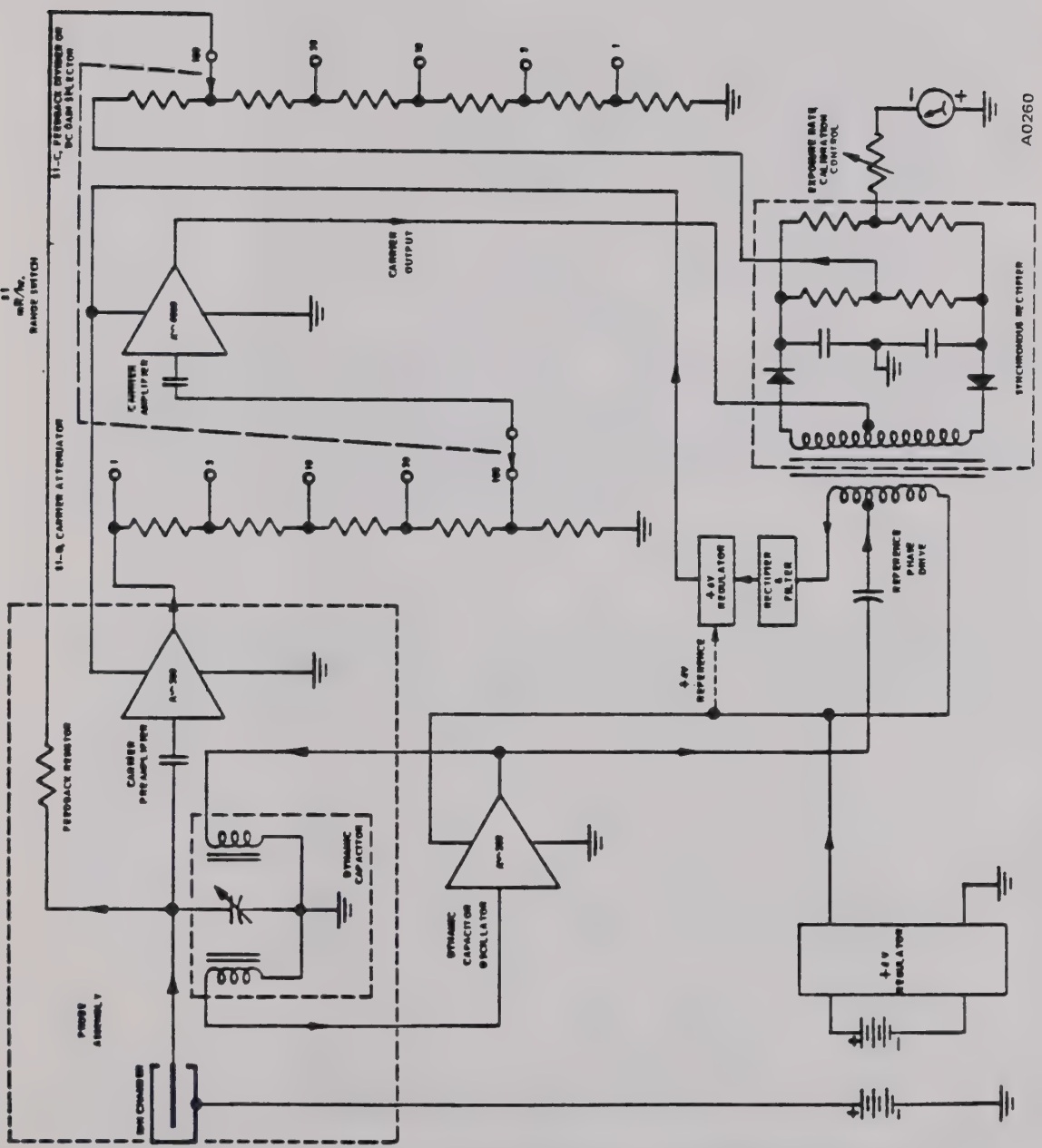


Figure 13. Model 440 RF/C Block Diagram

3.1 Circuit Description

3.1.1 +4 Volt Regulator - This circuit furnishes a stable, low-impedance supply voltage of +4.0 volts d.c. to:

- The dynamic capacitor oscillator; Q9, Q10 and Q11.
- The carrier output follower; Q3.
- The carrier input emitter follower; Q2.
- The carrier input source follower; Q1.
- The +6 volt regulator; Q4 and Q5 (as reference and power source).

D cell battery voltage from 6.2 to 4.6 volts feeds the regulator. The regulator controls about 50 mA total load current.

At turn-on, Q7 and Q8 are cut-off. Q6, the series pass transistor, is forward biased by R23. The output buss voltage rises until zener diode, CR23, goes into breakdown. Current then begins to flow in the series circuit made up of CR3, R27 and R28. The voltage drop caused by the current through R27 and R28 is applied as base bias to Q8. When the forward bias level of Q8's base is reached, about 0.6 volt, Q8 starts conducting, and acts through emitter followers Q7 and Q6 in such a way as to reduce the output voltage. Such a reduction is fedback by CR3 to Q8's base and the circuit attempts to rise again. All this action soon reaches an equilibrium condition, where the output voltage is equal to the base-emitter bias of Q8 plus the zener voltage of CR3. The zener voltage of CR3 is a log function of the current through it and R27 provides a means of adjusting this current from about .25 to 3 mA. R27 is normally adjusted for a supply output voltage of +4.0 volts.

3.1.2 Dynamic Capacitor Oscillator - This circuit is used to:

1. Voltage modulate input charge by means of a regularly varying capacitance.
2. Reference-phase drive the synchronous rectifier for demodulation purposes.
3. Create a d.c. supply voltage larger than that available from the D cell battery.

The circuit is powered from the +4.0 volt regulated buss.

The dynamic capacitor consists of a mechanically fixed, insulated plate and a moving, electrically grounded plate. The moving plate is part of

a mechanical resonant system which has a certain natural frequency of oscillation. See Figure 14. The moving plate also serves as a magnetic armature for both a solenoid driving coil and a variable-reluctance pickup coil.

A low-pass, high-gain amplifier is connected between these two coils. The amplifier consists of Q9, Q10 and Q11. At turn-on the forward biasing network of R34 and R36 causes a high static collector current in Q11. This current flows through the drive coil and it attracts the moving plate toward it. This motion generates a signal voltage in the pickup coil, which through amplification, serves to re-enforce the original motion of the plate. This continues until Q11 is saturated, and current in the drive coil is limited only by +4.0 volt supply. Shortly afterward, the maximum deflection of the moving plate is reached. As the motion slows and stops, little or no signal will be generated in the pickup coil and amplifier drive will fall off. The restoring forces in the mechanical system will now dominate and start moving the plate back toward its rest position. But the instant that the return motion begins, the pick-up coil and amplifier will again powerfully assist the motion. The opposite limit is set by the amplifier cutting off, where again plate momentum is overcome by the restoring force. As the plate moves back through the rest position, the cycle is complete. The oscillator frequency, which is controlled by the mechanical resonance, is nominally 300 Hz.

3.1.3 +6 Volt Regulator - This regulator has the function of supplying a quiet, regulated +6.0 volts to the integrated circuits UAR1 and UAR2. Approximately four volts enters transformer T2 on pin 4. Positive oscillator pulses add to this four volt d.c. level and the series combination is rectified and filtered by CR4 and C17. This yields about +8.0 volts. The series-pass transistor, Q4, forward biased by R21, swings the output buss up until the voltage divider, formed by R25 and R26, produces a voltage equal to the +4.0 volt buss plus the base-emitter junction drop of Q5. At which point Q5 starts conducting, which acting through emitter follower, Q4, tends to pull down the output buss. This feedback action stabilizes in a regulated output voltage of +6.0 volts $\pm$ 7%. The +4.0 volt supply serves as both the voltage reference and as the power source.

3.1.4 Ion Chamber - The ionization chamber serves as the input transducer of the instrument. It responds to an ionizing radiation field with the generation of a very minute direct current.

X or gamma radiation is made up of photons, or electromagnetic packets of energy. When these photons strike atoms of chamber wall material

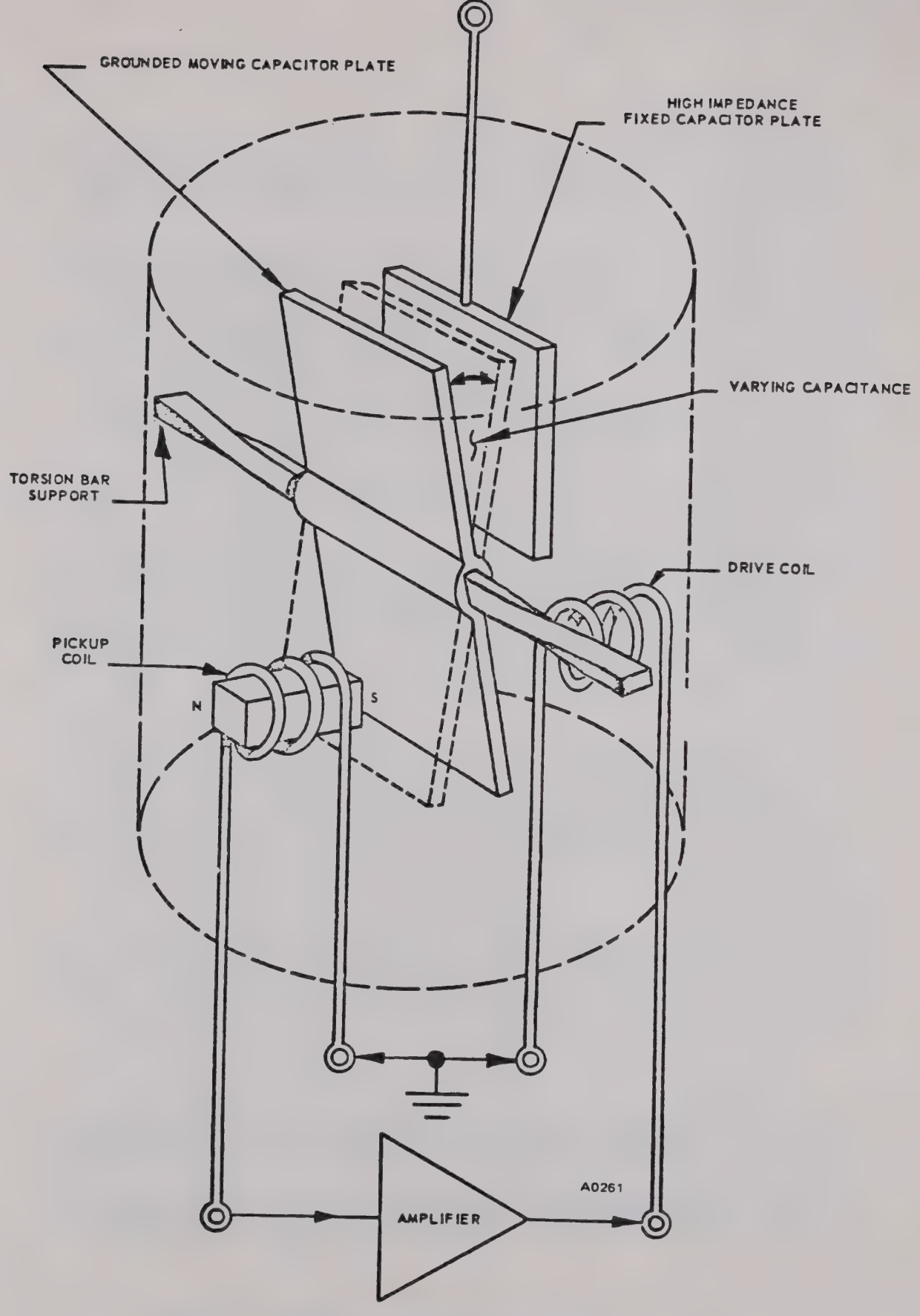


Figure 14. Dynamic Capacitor and Oscillator

(or air), some or all of the photon's energy is transferred into ejecting a high-speed electron from one of the inner orbits of the target atom. This electron speeds off through space striking the outer electron shells of wall and air atoms. These outer electrons are dislodged and travel off themselves, striking outer shells of other atoms, until all of the original high-speed electron's energy is converted into a long jagged track of ionized atoms.

Collection potential, applied between the chamber electrodes, collects the ions and electrons generated in the air volume before they can locally recombine and delivers them to the external circuit. Electrode geometry and spacing, and the collection voltage chamber and collection voltage, there is less than 0.1% of ions not collected at the maximum exposure rate measurable.

The ion chamber behaves in a bandpass manner, that is, it responds evenly only for a range of photon energies. At very low energies, photons are not able to penetrate the chamber wall material and so there is no internal high-speed electrons nor ion chamber current. In practice, the wall is made as thin and of as low-density a material as is necessary to achieve the desired low energy response. At very high energies, however, the situation is reversed and a minimum thickness of wall is necessary to prevent high speed electrons generated outside of the chamber from entering and contributing surpriously to the ion current. As a condition of measurement, all high-speed electrons are generated in either the chamber wall or internal air volume. Therefore, above a certain energy (about 250 keV) additional wall material must be added to insure non-response to outside electrons.

The external circuit to which the ion chamber furnishes its current is the dynamic capacitor electrometer. At typical temperatures and pressures the ion chamber delivers about 5×10^{-15} amperes when a uniform exposure rate of 1 mR/hr permeates the chamber volume.

Collection potential is supplied by battery BT5, which is always in the circuit.

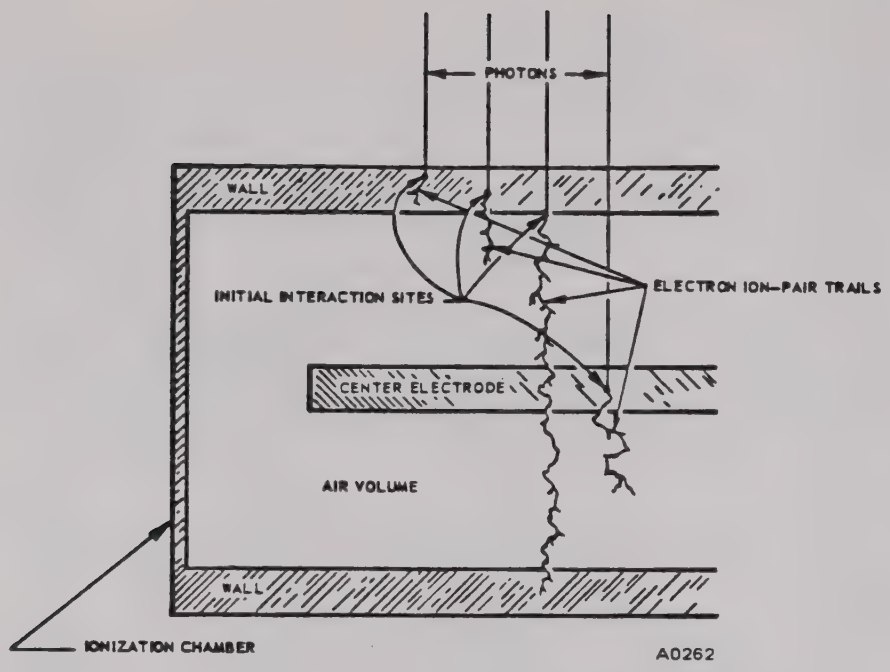


Figure 15. Cavity Ionization Chamber Operation

3.1.5 Dynamic Capacitor - The dynamic capacitor oscillator circuit (see section 3.1.2) drives a moving, grounded capacitor plate towards and away from a mixed, well-insulated capacitor plate. The two plates comprise the dynamic capacitor. The regular varying capacitance between the plates modulates any charge that flows into the capacitor. If the charge between the plates remains constant and the capacitance varies, then the voltage across the capacitor must vary inversely, since charge is defined as the product of voltage and capacitance.

Furthermore, the magnitude of the varying (or alternating) voltage will be directly proportional to the impressed d.c. voltage or charge. The alternating voltage will have the same frequency as the dynamic capacitor oscillator. This a.c. or carrier voltage can now be amplified with a stability not practical in a directly coupled amplifier.

An isolation resistor, R2, is employed to prevent chamber capacitance from shunting the dynamic capacitor and to allow operation when the feedback resistor, R1, is shorted, as during zeroing operation.

3.1.6 Carrier Preamplifier - After the input circuit charge has been voltage modulated by the dynamic capacitor, impedance transformation and voltage amplification is required. The carrier preamplifier consisting of Q1, Q2 and UAR1, performs this function. Capacitor C1 blocks d.c. and couples the 300 Hz carrier signal from the dynamic capacitor to the gate of the source follower, Q1. This junction field-effect stage steps down the circuit impedance almost a million times with only a slight loss in signal volage. Capacitor C2 couples output signal from Q1's source to the base of emitter follower Q2. A second stage of impedance step-down is necessary to drive the integrated circuit input circuit and the feedback network consisting of C3 and R4. The network provides in-phase drive to the low impedance end of R3, which effectively multiplies the actual resistance of R3 about ten times for a.c., but at d.c. still holds any gate-leakage effects to a negligible amount.

UAR1, the integrated circuit, develops the voltage gain (about 300) needed before leaving the probe assembly. C9 and C10 control the gain and bandpass of the integrated circuit.

The Carrier Preamplifier output is directly coupled to the Carrier Attenuator.

3.1.7 Carrier Attenuator - There are several reasons why it is desirable to have a constant loop (or reserve) gain in this type of instrument:

1. Error due to finite amplifier gain remains constant range-to-range and can be compensated for with a single adjustment.

2. The closed loop stability is improved by limiting loop gain on the less sensitive ranges.

3. Response time remains uniform from range to range.

In order to hold loop gain constant while closed loop gain is increased, the open loop gain must be increased. The open loop gain is controlled by the carrier attenuator, S1D, and R11 through R15. Switch decks S1D, the carrier attenuator and S1C, and the d.c. gain selector, are ganged together mechanically by the function switch shaft. They are wired in such a way as to produce a constant loop gain regardless of range which requires one switch arm to start up its divider as the other starts down its divider.

3.1.8 Carrier Main Amplifier - This circuitry is located on the main printed circuit board and consists of integrated circuit UAR2, emitter follower Q3, and transformer, T1. Final voltage and power gain for the carrier signal is secured by this section. Carrier signal is coupled and d.c. blocked by capacitor, C10, from the carrier attenuator to the input of integrated circuit UAR2.

The base of emitter follower, Q3, is directly coupled to UAR2's output. C12 and R16 control the gain and bandpass of UAR2. Emitter follower, Q3, drives T1, a 1:30 stepup transformer, whose secondary winding output is applied between the center tap of the synchronous rectifier winding on transformer T2 and ground.

3.1.9 Synchronous Rectifier - Demodulating the amplified carrier signal back into a d.c. level is the main function of this circuitry. It also serves to provide:

- Main d.c. feedback.
- Means for nulling the Contact Potential of the dynamic capacitor.
- Meter drive.

The secondary winding of T2 (see Figure 16) is energized by the dynamic capacitor oscillator. For about half of every cycle, both diodes CR5 and CR6 are simultaneously driven into conduction. This drive produces a $\pm$ 24 volts on either side of synchronous rectifier. During the interval when both the diodes are in conduction, carrier signal entering through the center-tap passes through the diodes and resistor diodes, CR5 and CR6, and capacitors C26 and C27, synchronously rectify and filter the carrier signal. The synchronous rectifier differs from conventional rectifiers in that no carrier signal path is available between carrier amplifier output and meter and feedback loads, until the reference oscillator drives the synchronous rectifier into conduction. Synchronous rectifiers can pass signals of both polarities once the reference oscillator has established the conduction path through the conducting diodes, CR5 and CR6. Three outputs are provided:

1. *Main d.c. feedback (the moving arm of R43, Balance Adj.).*

   The purpose of R43 is to adjust out any small imbalances and/or offsets in the synchronous rectifier circuit. This output feeds the d.c. gain selector, S1C.

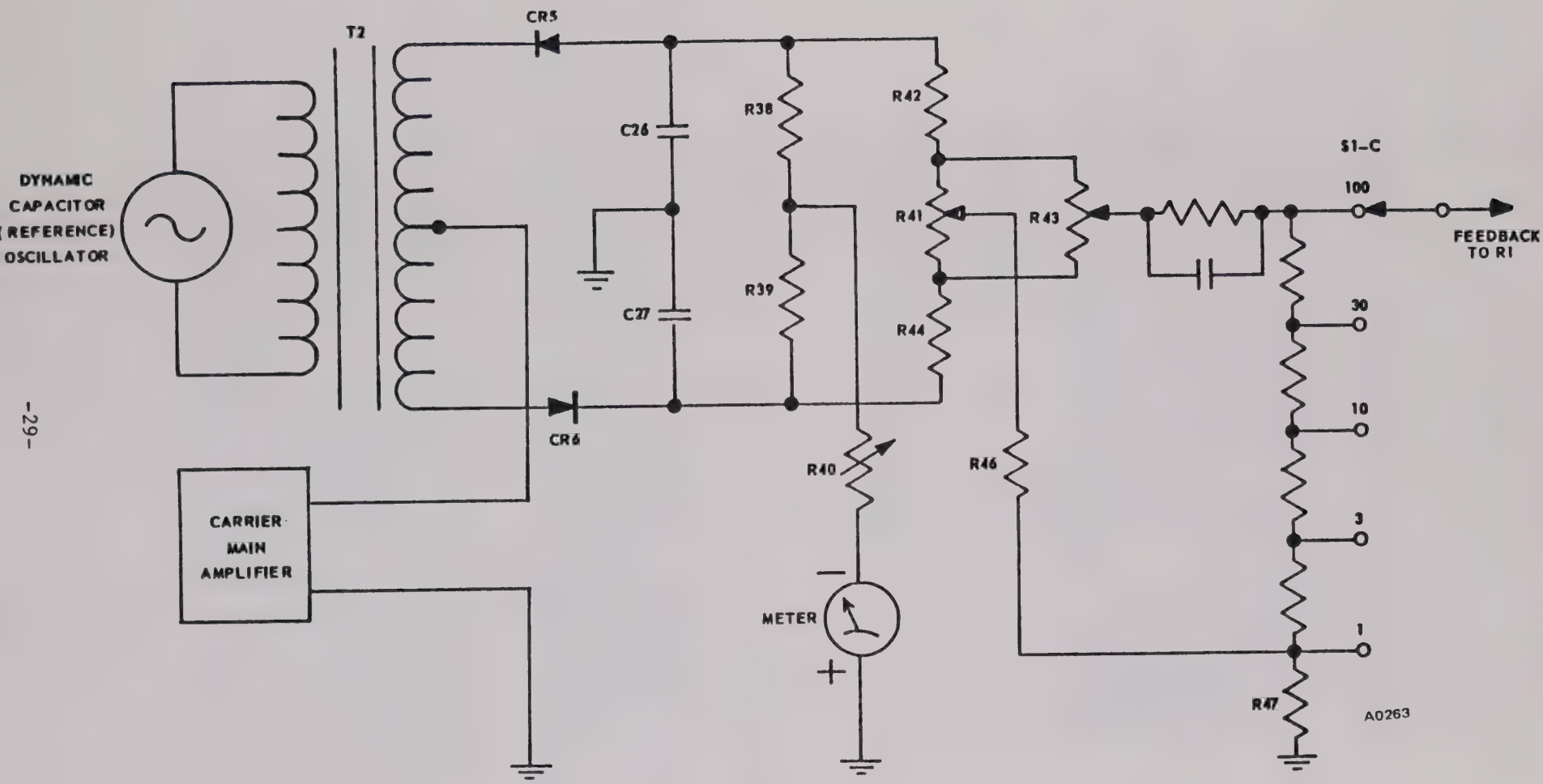


Figure 16. Synchronous Rectifier, Partial Schematic Diagram

2. *Contact Potential nulling feedback (the moving arm of R41, Zero Adj.).*

The purpose of this output is to null out the effect of dynamic capacitor contact potential on the more sensitive ranges. Contact Potential is equivalent to a tiny battery in series with the dynamic capacitor. Either polarity of contact potential may occur and it ranges from 0 to 10 mV. R41's moving arm can be adjusted to either side of center and thus set the polarity and magnitude of a current flowing into R46, such that the current causes a voltage drop across R47 in the same magnitude and polarity as that appearing, due to contact potential, in the input circuit. This nulls or zeroes the system.

3. *Meter Drive (junction of R38 and R39).*

Synchronously rectified and filtered carrier signal feeds through both R38 and R39, through the Exposure Rate Calibration Control, R40, and (when the function switch is in a range position) through the panel meter to ground.

3.1.10 Meter Circuit

3.1.10.1 Metering - A multiplier resistor, R29 or R40, is used in series with the panel meter depending on the metering mode used. This means the metering is performed in a voltmeter fashion. Since R29 and R40 are both very much larger in value than internal meter resistance, and possess low temperature coefficients, temperature effects in the metering are negligible.

Battery check is performed by measuring the regulated +4.0 volt buss. R29, a precision film resistor, determines the current flowing through the meter and shunt resistor, R37, such that the meter indicates in the shaded zone when buss voltage is +4.0 volts.

Exposure Rate indication is performed by measuring the voltage occurring at the junction of R38, R39 and R40. The indication can be varied by means of the Exposure Rate Calibration control, R40, for any given voltage. This is the means by which calibration is performed.

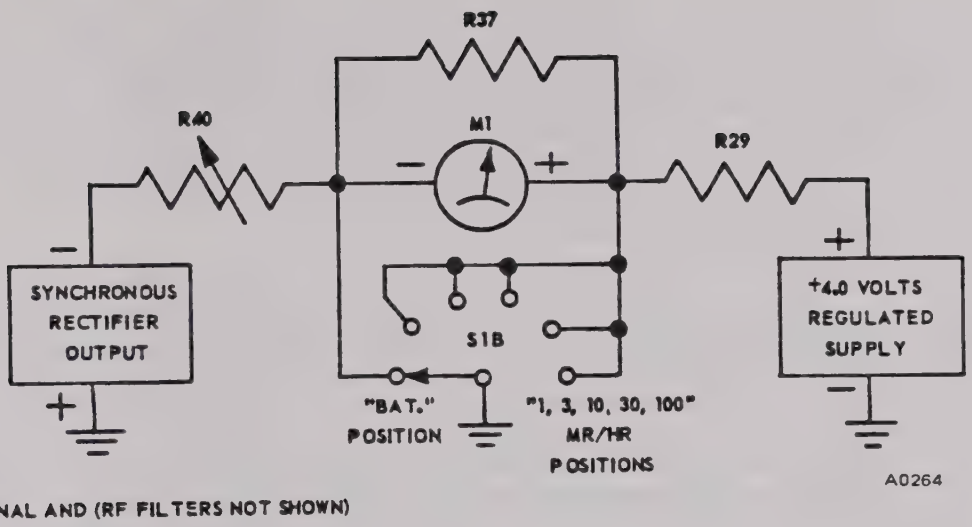


Figure 17. Simplified Meter Circuit

3.1.10.2 Meter Switching - The panel meter, M1, is wire permanently between the exposure rate calibration control, R40, and the +4.0 volt multiplier resistor, R29. The function switch section, S1B, selects the proper metering mode by means of a moving ground. See Figure 17. When the function switch is in the Bat. position, the negative side of the meter and the meter side of R40 are grounded. This allows the +4.0 volt multiplier resistor, R29, current to drive the meter, and shunts current arriving from the synchronous rectifier through R40, unmetered into ground. In the 100, 30, 10, 3 and 1 mR/hr positions, the situation is reversed and the multiplier current is shunted to ground, and the synchronous rectifier current allowed to pass through the meter.

3.1.10.3 Meter Dampening - The panel meter, M1, is at all times, shunted by R37, a resistor that is used to critically dampen the meter electrically, that is, obtain the fastest meter action but with a low amount of overshooting of the final indication.

3.1.10.4 Meter Signal Filtration - Capacitors C36 and C37 in shunt with the meter's internal resistance form a long time constant RC filter which reduces the displayed amplitude of source statistics and

electronic noise. This filtration, however, accounts for a large fraction of the overall response time.

3.1.10.5 Meter RF Filtration

3.1.11 Case and RF Filter - The insensitivity of the instrument to RF and electrostatic fields is obtained by completely enclosing the instrument in a conducting, metal case. The magnesium window provides a low-energy radiation entrance to the case, while maintaining the metal shield integrity. The leads to the panel meter, which is not included within the main shielded cavity, are routed through double pi-section filters, each section of which is isolated in its own shielded compartment. The basic case and filter design has been tested successfully in high intensity RF fields from the microwave region on down.

Magnetic insensitivity is achieved through the use of all solid state circuitry, and a magnetically insensitive type of radiation detector.

4 Equipment and Techniques required

4.1 Test Equipment

D.C. Voltmeter:

- Maximum Inaccuracy; ± 5%.
- Resolution; At least three ranges between 0 to 60 volts.
- Loading; 20 KΩ/V or higher input resistance.
- Typical Instrument; Triplett 630 VOM, Simpson 260 VOM, Fairchild 7050 DVM, RCA WV-77E VTVM.

Oscilloscope:

- Maximum Inaccuracy; ± 5%.
- Sensitivity; 10 mV/Div. to 10 V/Div.
- Time Base; 0.3 to 1.0 mS/Div.
- Loading; 200 pF (or less), shunting 1 megohm or more).
- Typical Instrument; Tektronix 561 (A, B) with 3A72 and 2B67 plug-ins, Hewlett Packard 120B.

4.1.1 Tools - The usual assortment of hand tools will suffice; no special tools or jigs are required for normal servicing.

Several sizes of regular slotted recess screwdrivers and nut drivers will be helpful as well as soldering and desoldering tools.

4. 1.2 Techniques - The major servicing technique required will be the proper removal and replacement of components on the main printed circuit board. These operations can be broken into the following steps.

Component Removal:

1. Heat and remove all free solder from the component pads. Either a special vacuum desoldering tool or drawing the solder off onto a hot tip which is continually wiped clean, can be used.

2. Unbend carefully any bent or crimped-over component leads.

3. Reheat leads and pads and remove component.

N O T E

An exception to the usual de-soldering practice will be the integrated circuit, UAR2. This is a twelve-lead device with the pads arranged in a half-inch diameter circle. The proper way to desolder such a component is to use a special desolcering cup-tip, Ungar #856, after all free solder has been removed and leads straightened. This same cup-tip may be used to remove the dynamic capacitor oscillator transformer, T2.

Component Replacement:

1. Inspect and, if necessary, clear pad holes so that the component leads easily fit through the board without heating.

2. Bend leads to secure component.

3. Resolder leads to pads; use fresh rosin-core solder.

A good general caution to observe in both soldering and desoldering operations is to use a minimum of heat. Good wetting heat is desirable but excess heat will weaken the pad to circuit board bond. Also, semiconductors are likely to degrade or fail from excessive heat application.

4.2 Mechanical Disassembly (and Reassembly) and Adjustment Procedures - The standard procedures listed below are called for by maintenance instructions located elsewhere in this section.

4.2.1 Case-Top Assembly Removal (and Replacement)

Removal:

1. Turn the instrument off; rotate the function selector to its extreme counter-clockwise position, OFF.

2. With a screwdriver, remove the eight panhead screws which secure the case-top assembly to the case bottom.

3. Slowly, and with care (see Figure 18) grasp the carrying handle and lift up only the handle end of the case-top assembly.

C A U T I O N

The ion chamber's 1/4 mil mylar window can be easily damaged by case-bottom metal work if these instructions are not followed.

4. Continue lifting only the handle end of the case-top assembly until the battery box and printed circuit board corner clear the case bottom.

5. Withdraw the case-top assembly to the rear, while completing the lift-out operation. This completes the case-top removal procedure.

Replacement:

1. Simply reverse the above procedure.

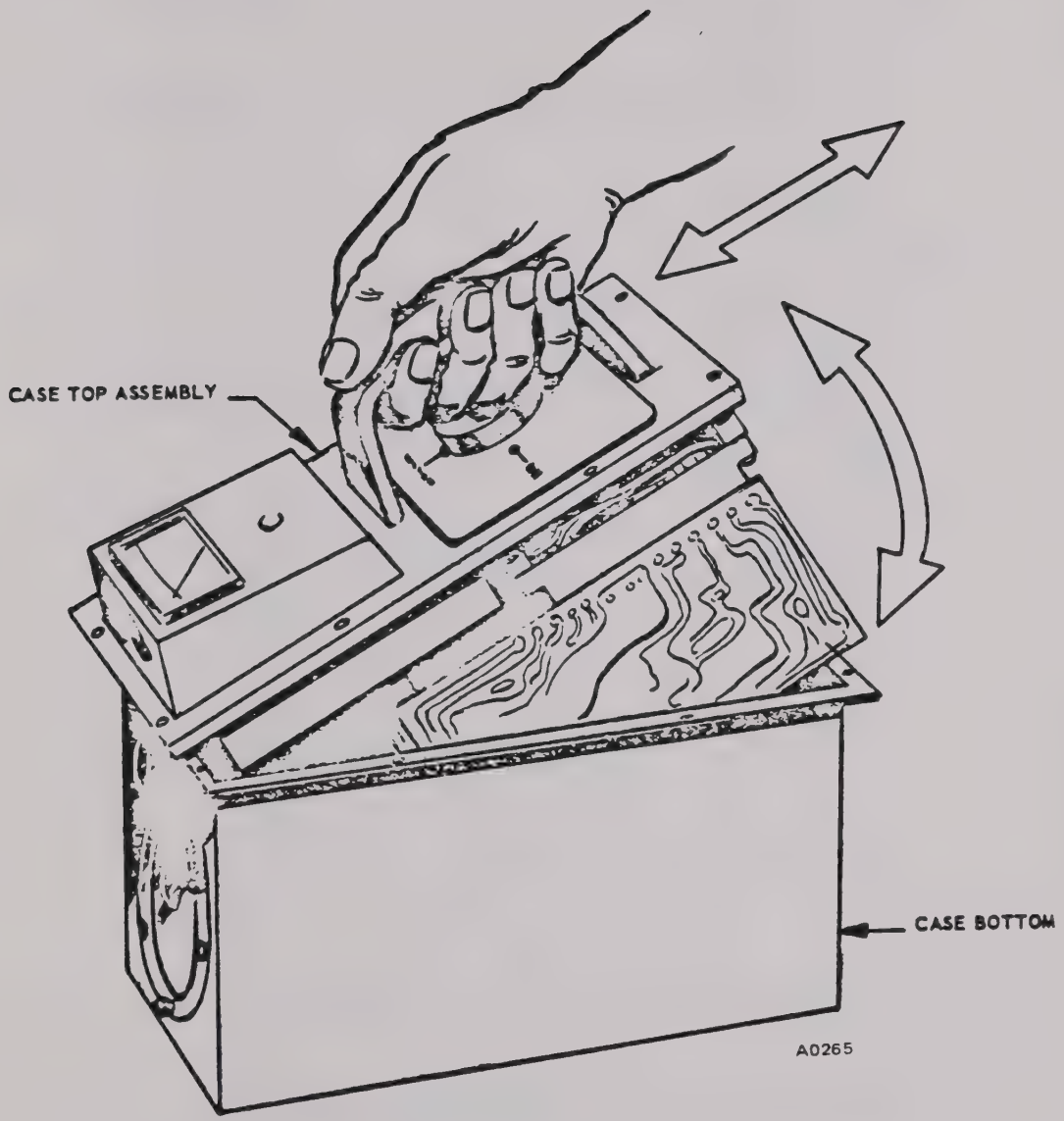


Figure 18. Case Top Assembly Removal and Replacement

4.2.2 Battery Clip Removal (and Replacement)

Removal:

1. If not already performed, perform 4.2.1, Removal and Replacement.

2. Turn case-top assembly upside down and rest the handle and meter box on a flat surface.

3. Unsnap the battery clip reverse-bend end from the slot in the battery box.

4. Rotate the clip up away from the battery box (see Figure 19).

5. The hooked end of the battery clip can now be disengaged from its battery box slot. This completes the battery clip removal.

Replacement:

1. Simply reverse the previous procedure.

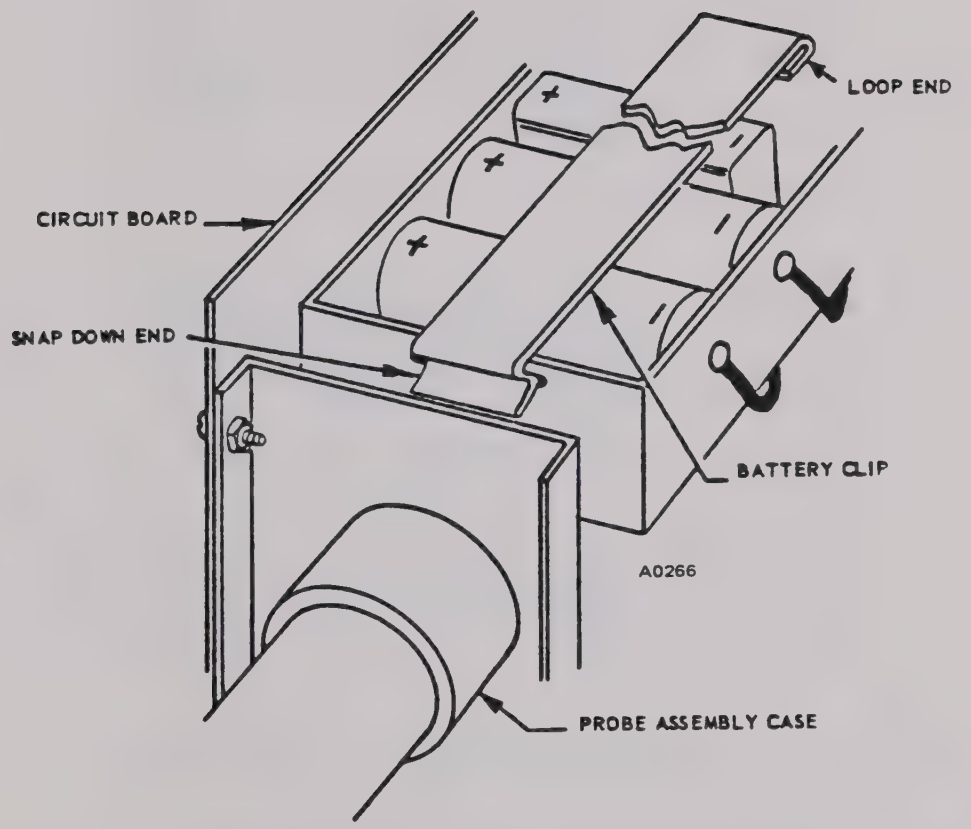


Figure 19. Battery Clip Removal and Replacement

4.2.3 Battery Removal (and Replacement)

1. If not already performed, perform paragraph 4.2.1 Removal then 4.2.2 Removal.

2. D Cell Removal:

   Grasping the battery box with one hand, insert the thumb or index finger of the other hand into the space between the positive end of the cell and battery box wall. Firmly press the cell into the large spiral base spring and at the same time tip out the positive end of the cell. When the positive end of the cell is clear of its contact, the cell can be lifted free of the battery box. See Figure 20.

3. D Cell Replacement: Make sure of the correct polarity of cell and simply reverse the above procedure.

4. Collection Battery Removal: Grasping the battery box with one hand, insert the thumb or index finger of the other hand into the space between the positive end of the battery and battery box wall. Firmly press the negative end into the weld-bracket and tip positive end out.

5. Collection Battery Replacement: Make sure of the correct polarity match, and insert the positive end of the battery firmly pressing it into its contact spring. The negative end of the battery may now be snapped down into the weld bracket. The raised dimple in the weld bracket should be seated into the recess in the battery's negative contact. This completes the replacement of the collection battery.

4.2.4 Circuit Board Removal (and Replacement)

Removal:

1. If not already performed, perform 4.2.1 Removal.

2. Turn upside down and rest on handle and meter box.

3. With a screwdriver remove the two screws, insulative flat washers and nuts that secure the printed circuit board to the front bracket.

4. Grasping the unfastened circuit board in one hand and case-top assembly in the other, tip out the board's connector, P2, from the chassis connector, J2.

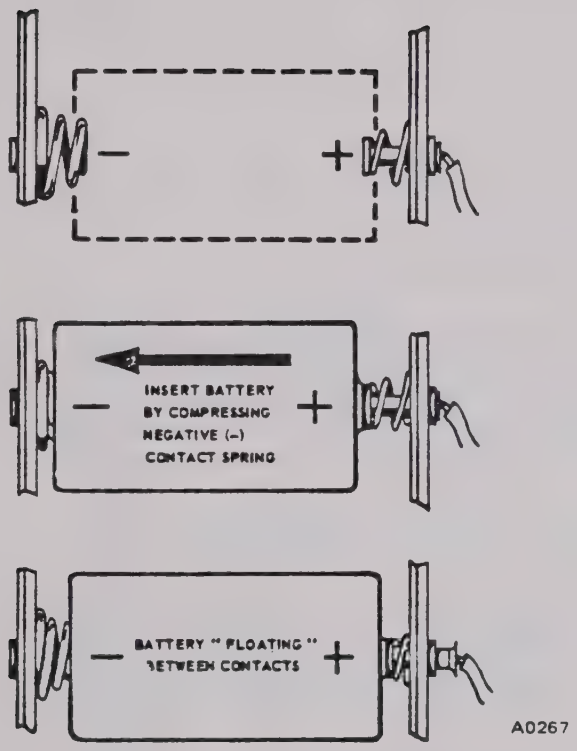


Figure 20. Battery Removal and Replacement

Replacement:

1. Simply reverse the above procedure.

N O T E

When replacing the circuit board be sure to replace all insulator flat washers exactly as found. If metal flat washers (or none at all) are used, circuit board printing may be shorted to ground.

4.2.5 Probe Assembly Removal (and Replacement)

1. Perform paragraph 4.2.1 Removal.

2. Perform paragraph 4.2.4 Removal.

3. Grasp the case-top assembly in one hand and with the other hand's thumb and index finger grasp the outermost collar of J1, chassis cable connector, and firmly pull the collar straight back. The connector's locking pieces will release and the connector J1 can be drawn away.

4. On the front bracket is fastened the probe assembly clamp (see Figure 21). With a screwdriver, loosen the screw and clamp.

5. With one hand steadying the case-top assembly and gently holding the probe assembly in place, remove the three screws fastening the probe assembly to the rear bracket.

C A U T I O N

Do NOT tip the case-top assembly up, such that any part of the weight of the assembly rests on the ion chamber. Also, as the last screw is removed, make certain the probe assembly does not fall free, as it will likely land on and damage the ion chamber. Do NOT handle or carry the probe assembly by means of the ion chamber.

Withdraw the probe assembly from case-top assembly. This completes removal of the probe assembly.

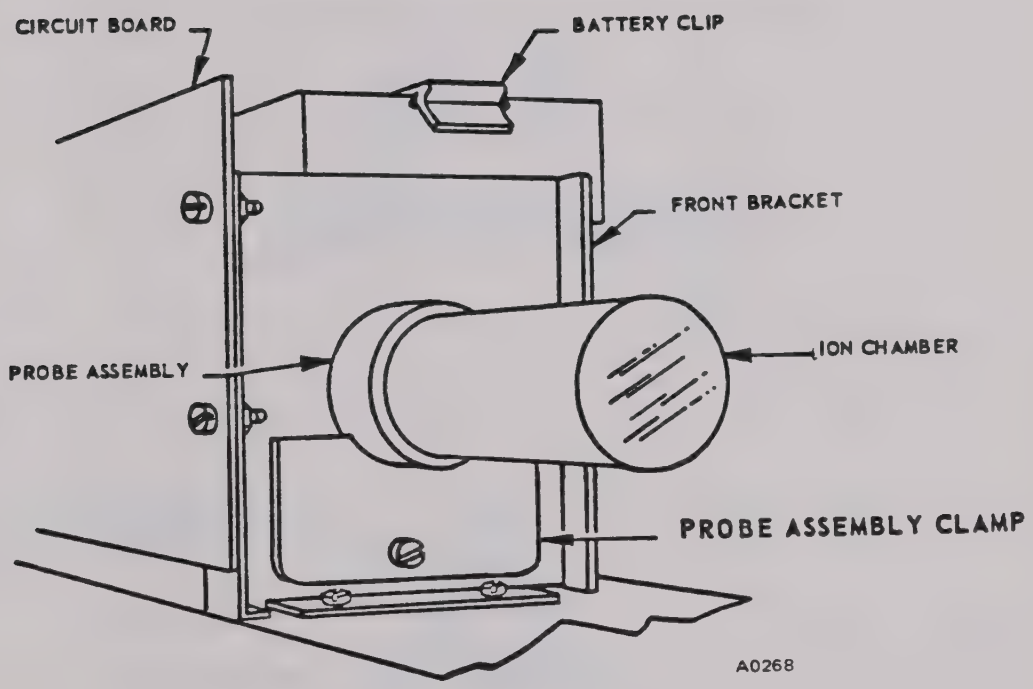


Figure 21. Location of Probe Assembly Clamp

Replacement:

Simply reverse the above procedure, except:

1. The probe assembly should be rotated on its axis until the locating key on P1 aligns as shown on Figure 22. Proper alignment greatly reduces motion sensitivity of the instrument.

2. Do NOT tighten the probe assembly clamp screw.

3. Do tighten securely the three screws holding the probe assembly to the rear bracket.

4. Perform procedure in paragraph 4.2.8.

This completes probe assembly replacement.

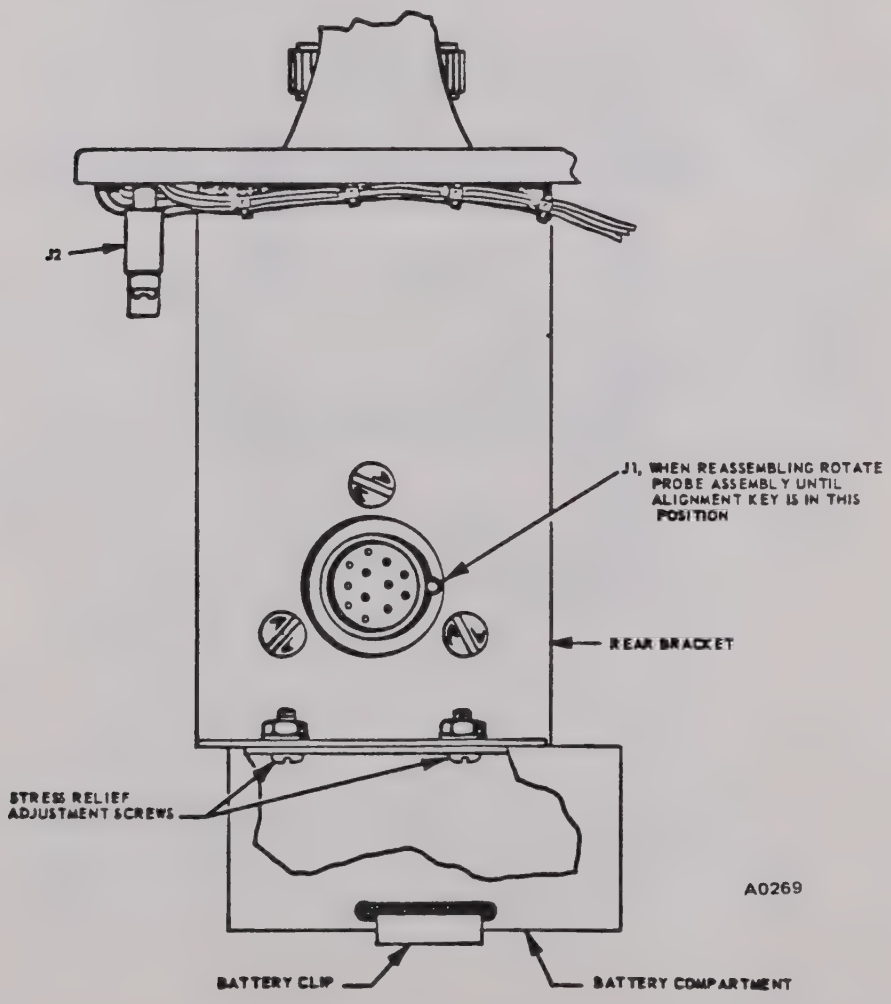


Figure 22. Probe Assembly Alignment

4.2.6 Chamber Shell Removal (and Replacement)

1. Perform 4.2.1 Removal.

2. Perform 4.2.4 Removal.

3. Perform 4.2.5 Removal.

4. Carefully remove the three nylon (or metal) screws that fasten the ion chamber shell to the chamber floorplate.

5. Slip the chamber shell off.

N O T E

When the chamber shell is off, inspect it to see if one of its three mounting holes is in an open-ended slot. If it is, future chamber shell removals and replacements may be performed without removing the circuit board (4.2.4) or the probe assembly (4.2.5). That is, steps 2 and 3 above may be deleted. If one hole is not slotted, it may be at this time by the following procedure.

Take a pair of small diagonal cutting pliers and carefully cut through the shell on two lines, in from the bottom edge of the chamber shell. Do NOT slot more than one hole in this manner, as the effective chamber volume will no longer be controlled accurately, and hence, calibration accuracy will not be maintained. (See Figure 23).

When a chamber shell has been so modified, the screw used with the open-ended slot no longer has to be removed, but merely loosened, in order to remove the shell.

Replacement:

Simply reverse the above procedure, depending on whether or not probe assembly and circuit board replacement is necessary. The chamber shell should be aligned with the probe assembly in such a way so as to place the open-end, slotted side in the blind when locating key of P1 is properly aligned. All that will be required then is tighten the loosened screw, some fraction of a turn, with the edge of a screwdriver blade.

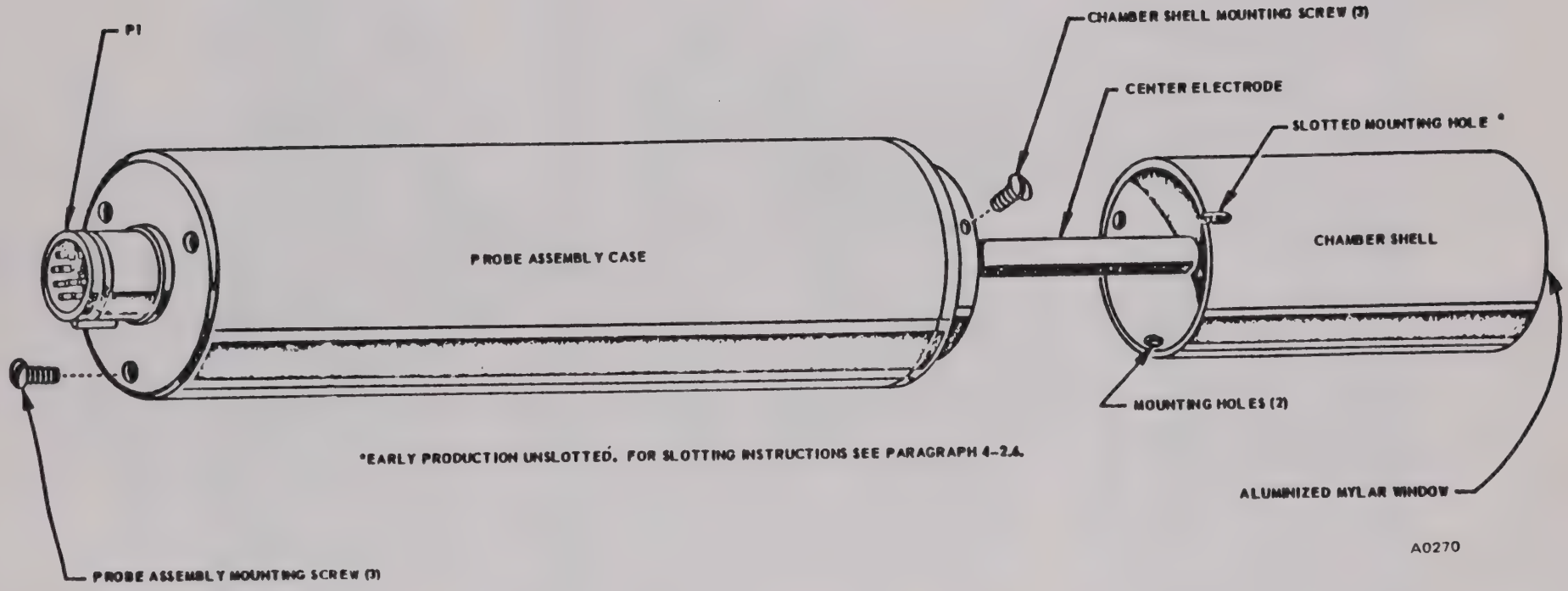


Figure 23. Probe Assembly and Chamber Shell Exploded View

4.2.7 Circuit Board Access for Trouble Shooting - In order to more easily gain access to testpoints for the purposes of measuring voltages or viewing waveforms, the circuit board may be deployed, so that the component side of the circuit board is available to test equipment probes. The following procedure deploys the board.

1. Perform procedure 4.2.1 Removal.

2. Perform procedure 4.2.4 Removal.

3. Remove the screws and phenolic spacers, fastening J2 to the case-top assembly weld nuts (see Figure 24).

4. Dress J2 and its associated cabling out and away from the case-top assembly and at an angle such that when the circuit board is re-inserted, the component side leads will be very accessible but so that there is no danger of grounding printing or lugs of J2 on the case-top assembly edge.

5. Re-insert the main circuit board into connector J2. The main circuit board is now deployed for probing.

Replacement:

Simply reverse the previous procedure.

4.2.8 Probe Assembly Stress Relief Adjustment - Mechanical stress on the probe assembly, either directly or indirectly through the flexing of the case-top assembly, causes internal insulators to generate piezo-electricity. This causes spurious up and down-scale indications. It can be minimized by relieving as much mechanical stress as possible on the probe assembly. This is done through the following procedure.

1. Perform procedure 4.2.1.

2. Perform procedure 4.2.2.

3. Loosen probe assembly clamp screw, if not already loosened.

4. Remove rearmost D cell, that cell closest to the handle end of the casetop assembly (see procedure 4.2.3 D Cell removal). Refer to Figure 22.

5. Loosen with a screwdriver the screwheads exposed by the D call removal. Also loosen the screws fastening the front bracket to the case-top assembly.

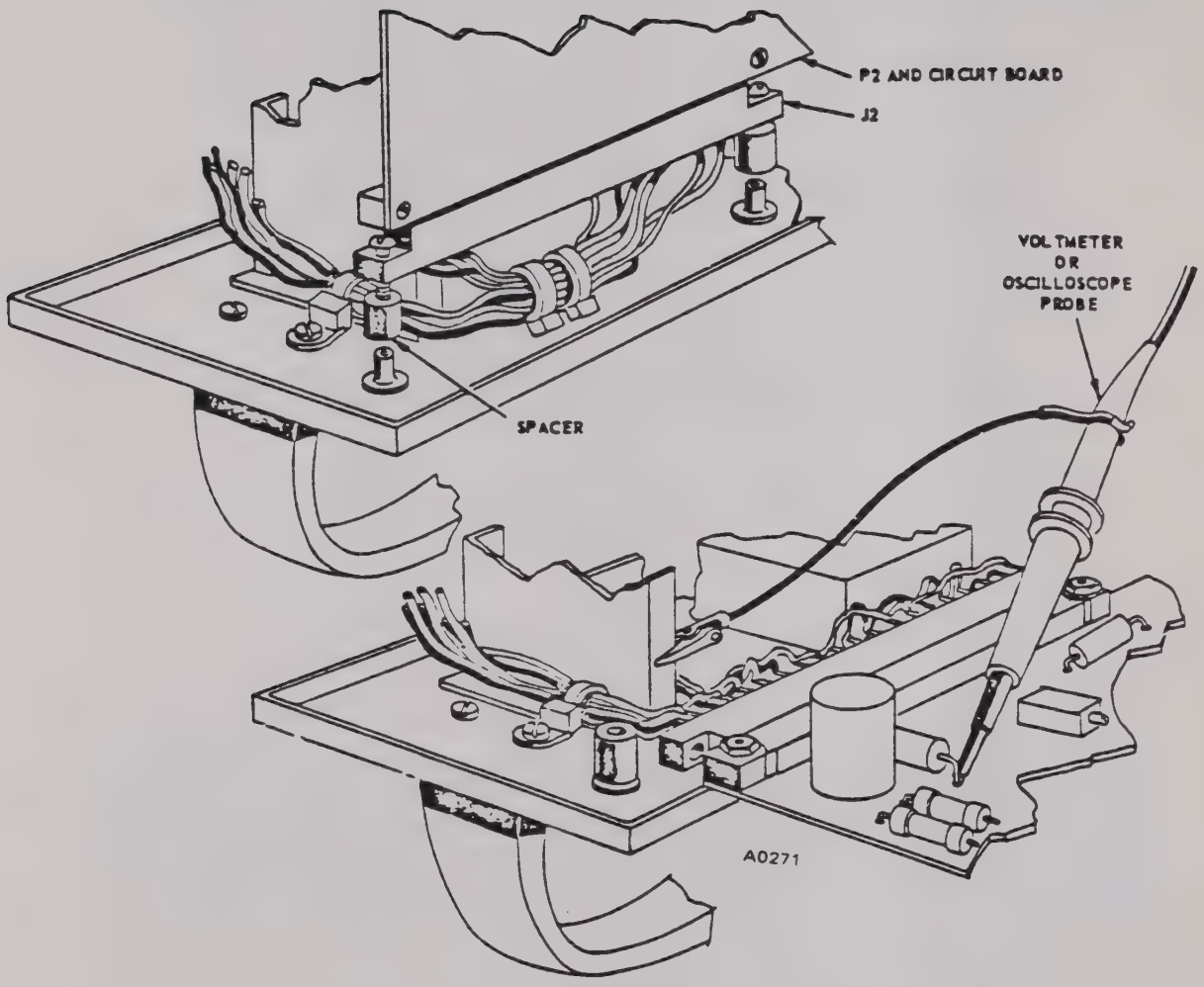


Figure 24. Circuit Board Deployment for Probing

6. Adjust the brackets so that the probe assembly naturally positions itself with near equal spacing on all sides in the front bracket opening. If this cannot be completely achieved, at least adjust the brackets in such a way that there is a minimum of force drawing the probe assembly toward any rim point.

7. Tighten bracket screws.

8. Adjust probe assembly clamp so that there is a minimum of play of the probe assembly in the front bracket opening. Do NOT place the probe assembly under stress with the clamp.

9. Tighten the probe assembly clamp screw. This completes the probe assembly stress relief adjustment.

4.3 Preventive Maintenance

4.3.1 Batteries - Four D cells and a 22-1/2 volt battery make up the prime power source of the instrument. The life expectancy of the D cells will be much shorter than the 22-1/2 volt battery under almost any use circumstances. Whenever a battery check discloses failing cells (see section 2.1), or whenever the instrument is being stored indefinitely or for several months at least, all batteries should be removed (see procedures 4.2.1, 4.2.2 and 4.2.3). Unfortunately modern batteries are still not leak proof. Electrolytic seepage from a spent battery, through use or shelf life, can so severly corrode the interior of the battery compartment that it must be replaced.

If the instrument receives intermittant use, a replacement schedule of six months for the D cells should be followed. The 22-1/2 volt battery is not monitored in any way. Because it is used only for ion collection, it is essentially unloaded. Shelf life varies with average ambient temperature, but a regular, yearly replacement schedule would be a good, conservative maintenance policy.

4.3.2 Switches and Connectors - The noble metal coatings on the surfaces of the function switch and connector contacts may oxide or sulphide over a long period of time. If inspection shows a buildup and/or the instrument becomes excessively noisy or behaves erratically, cleaning is in order. Any commercially available contact solvent/lubricator products may be used on the switch and connector contacting surfaces. Battery contacts may be similarly checked and treated.

4.3.3 Miscellaneous - At some regular interval the instrument's accuracy should be checked. The operational check source is adequate for this purpose (see section 2.8).

Shock and vibration over a long period of time can cause hardware to loosen and/or cables and leadwires to fatigue and break. Check cable terminations for fraying or broken leads. Check and tighten the function switch knob and any loose hardware.

4.4 Troubleshooting

4.4.1 General - First, make certain that a malfunction exists. Read section 2, Operating Instructions carefully in order to determine whether or not the observed condition is normal, or whether or not the instrument is being operated properly. After this has been done, re-check the battery power supply even if the preventive maintenance recommendations in Section 4.3.1 have been followed rigorously. When it has been ascertained that the instrument is truly malfunctioning, the user may, at his option, contact the factory for advice about return and repair or attempt the following troubleshooting routines.

The strongest technique in troubleshooting is to systematically localize the source of the trouble. This is done by first checking out those circuits which are common to the whole instrument, such as power supply circuits, and then individual branch circuits. The following three troubleshooting charts should help pinpoint trouble rapidly to a circuit or component.

Troubleshooting Chart I lists operating abnormalities (or symptoms) in the first column, and then some possible causes of that trouble in the middle column. Finally, the corrective action or advice for such a cause is listed in the column at the far right.

Whenever difficulty is experienced in localizing trouble and/or the trouble seems to be of an intermittant nature, a close physical inspection of all solder joints and leadwire terminals is suggested. If a connection looks doubtful at all, carefully heat and resolder the point, using fresh solder if necessary.

4.4.2 Power Supply System - At the outset of this section it will be presumed that sections 2.1, 3.2.1 and 4.4.1 have been observed in regards to the battery power supply's evaluation and maintenance. For proper continuity in the switch and connector portions of the battery circuit, see Troubleshooting Chart I, first symptom/cause group. Di-

TROUBLESHOOTING CHART I

SYMPTOMS AND POSSIBLE CAUSES	REMEDIES
No (or Low) battery Check and No Response To Ionizing Radiation	
1. Dead batteries, BT1-BT4.	1. Install fresh batteries.
2. Dead batteries, BT1-BT4.	2. Same as above.
3. Shorted (or heavily loaded) + 4 V buss.	3. Find and clear short or abnormal load, see section 4.4.2
4. + 4 V regulator not operating	4. See section 4.4.2.
5. Switch (S1A), connector P2-J2 contacts H, L and M) or battery contacts (BT1-BT4).	5. Clean, repair or replace contacts.
Battery Checks O.K., but No Response To Ionizing Radiation	
1. Dynamic capacitor oscillator not operating.	1. See section 4.4.3.
2. +6 V regulator not operating.	2. See section 4.4.2.
3. Synchronous rectifier not operating.	3. See section 4.4.5.
4. Carrier amplifier not operating.	4. See section 4.4.4.
Battery Checks O.K., Instrument Responds to Ionizing Radiation, but Erratically On All Ranges.	
1. Collection battery BT5 is missing.	1. Install collection battery BT5.
2. Signal cable conductor broken and intermittently making contact. (Either 300 Hz signal or d. c. feedback signal).	2. Inspect switch decks (S1C and D) and connector sets P1-J1 and P2-J2, on those lugs which signal cables terminate. Repair broken conductors, center or ground braid.
3. Switch (S1C or D) contacts.	3. Clean, repair or replace contacts.
4. Chamber conduction dog paths broken.	4. Factory repair only.
5. Component failure in Probe Assembly.	5. Factory repair only.

TROUBLESHOOTING CHART I (CONT'D)

SYMPTOMS AND POSSIBLE CAUSES	REMEDIES
Battery Checks O.K., Instrument Responds to Ionizing Radiation but Indicates Low and/or Much Slower Than Usual	
1. Bad Synchronous rectifier (diode(s), CR5 and/or CR6.	1. Replaces CR5 and/or CR6.
2. Dead collection battery, BT5.	2. Install fresh battery, BT5.
3. Low (or inoperative) +6 volt regulator.	3. See section 4.4.2.
4. Component failure in Prove Assembly.	4. Factory repair only.
Battery Checks O.K., Instrument Responds to Ionizing Radiation but Indicates Steadily Downscale (Beneath Zero) with (or without) Ionizing Radiation Being Present.	
1. Probe Assembly's Insulators Badly Strained by Mechanical Shock or Vibration.	1. Turn instrument off and let rest for 24-48 hours.
2. Bad synchronous rectifier diode(s), CR5 and/or CR6.	2. Replace CR5 and/or CR6.
3. Dead (or missing) collection battery, BT5.	3. Install fresh battery, BT5.
4. Reversed collection battery, BT5.	4. Reverse Battery, BT5.
5. Signal cable conductor broken and feedback loop broken. (Either 300 Hz signal or d.c. feedback signal).	5. Inspect switch decks (S1C and D) and connector sets P1-J1 and P2-J2, on those lugs which signal cables terminate. Repair broken conductors, center or ground braid.
6. Balance or zero adjustment out of adjustment.	6. Readjust; see section 4.5.2 or section 4.5.3.

rect shorts across +4V regulator are presumed cleared.

4.4.2.1 +4.0 Volt Regulator

1. Measure the d.c. voltage drop across zener reference diode, CR3. It should be 3.4 volts, ± 5%, for R27, + 4.0 volt Reg. Adj., adjusted approximately midway in its mechanical travel.

2. Measure the d.c. voltage from pin H of P2-J2 to circuit ground. For fresh batteries, BT1-BT4, the voltage should be at least -2.0 volts, at normal load.

3. Check emitter-base biases on Q6, Q7 and Q8, by means of Troubleshooting Chart II.

4. Check total + 4V load current demand by means of unsoldering the lead from pin H of J2 and inserting the d.c. milliammeter in series with the lead and pin H. Normal biases are correct, the battery drain will be 72 mA (± 5%). (If the dynamic capacitor is NOT oscillating, but d.c. biases are correct, the battery drain will be 72 mA, ± 10%).

4.4.2.2 +6 Volt Regulator

1. Proper operation of +4.0 volt regulator and a good set of batteries is presumed.

2. There must be proper operation of the dynamic capacitor oscillator before the +6.0 volt regulator will operate. See section 4.4.3.

3. Measure the d.c. voltage from the collector of Q4 to ground. The voltage should be +8 volts, ± 15%.

4. Check emitter-base biases of Q4 and Q5 by means of Troubleshooting Chart II.

5. Check total +6 volt load current demand by means of unsoldering the cathode end of CR4 and inserting a 0-10 (or 0-12) milliammeter in series. Normal current demand is 4 mA, ± 20%.

4.4.3 Dynamic Capacitor Oscillator - The amplifier part of the Dynamic Capacitor Oscillator consists of Q9, Q10 and Q11 and is located on the printed circuit board. The dynamic capacitor itself is located in the Probe Assembly, which is not normally field serviced (see Section 4.4.6).

If it has been established that the battery supply and the +4.0 volt regulator are in good working order but the oscillator does not run, and there is an absence of signal at testpoint 4, turn the instrument off and make the following continuity checks.

1. With an ohmmeter measure the resistance from P2, Pin R to chassis ground. The resistance should be between 45 and 55 ohms.

2. Measure the resistance from P2, pin A to chassis ground. The resistance should be between 150 and 200 ohms.

3. Resistances higher than those indicate open (broken) leads in the harness, dirty connector contacts, or an open drive or pickup coil in the dynamic capacitor. Use Figure 30 to isolate the open circuit to either the probe assembly or harness.

   Resistances lower than those specified indicate leaking or shorting wiring or components and may be isolated as above.

The transistor leadwire voltages for Q9, Q10 and Q11 given in Troubleshooting Chart II are non-oscillating d.c. values. They are given rather than oscillating values because d.c. voltmeters tend to indicate unpredictably when there's a large unsymmetrical a.c. signal superimposed. Also it is more probable that oscillator circuit trouble will be of the not-oscillating variety. The non-oscillating values allow an immediate check of all the d.c. biases and operating points in the oscillator. To check the bias values in an oscillator that is running, simply short P2, pin A to ground with a short clip lead.

Odd distortions in test point (4) waveform or weak operation of the oscillator can often be traced to troubles in the Synchronous Rectifier circuit, which forms one of the major loads on the oscillator. The +6 volt regulator is another tightly coupled load on the oscillator. Trouble in these associated circuits can be determined by unsoldering one end of either CR4, CR5, CR6 or C25, and observing the effects on the waveform.

When the instrument is operating and switched to the most sensitive range, 1 mR/hr, noise feedthrough from the Carrier Amplifier will be observed as a time-base jitter, on the drive-coil waveform at test point (4). This is entirely normal.

4.4.4 Carrier Attenuator and Amplifier - The Carrier Attenuator, S1D, receives its signal input from the Probe Assembly and sends its output to the Carrier Amplifier on the printed circuit board. The most likely causes of trouble will be cable leadwire breakage or switch contact oxide films.

The Carrier Amplifier, UAR2 and Q3, amplifies the Carrier Attenuator output to drive the Carrier Output Transformer, T1. Standard signal tracing techniques can be used when troubleshooting the Attenuator and Amplifier. Check for noise and/or carrier signal on test point (9). Then check test point (8) and (7). The waveform shapes and amplitudes for full scale meter deflection are given in Troubleshooting Chart III. The full scale signal level at the top of the Carrier Attenuator depends upon which range is selected.

RANGE	1	3	10	30	100	mr/hr	Full Scale
Signal at top of Carrier Attenuator, S1D, for 10 mV p-p at test point (7).	10	35	100	350	1000	mV	Peak-to-Peak (Approx.)

As in other circuit sections, the d.c. voltages on the integrated circuit and transistor leadwires may be checked by means of Troubleshooting Chart II. That is, furnishing an input signal (radiation field) to the system and then starting with the output stage probe progressively further back into the circuitry until the signal is found and thus the malfunctioning circuit section localized.

As a further aid, Troubleshooting Chart II lists all accessible transistor and integrated circuit leadwire d.c. voltages in the instrument.

N O T E

Because this instrument makes use of a high degree of negative feedback if there is a gross component failure or any other malfunction which causes the signal/feedback loop to be broken, saturation signals (with consequent waveform distortion) will occur.

4.4.5 Synchronous Rectifier and Feedback Divider - Synchronous Rectifier troubles can be traced by means of Troubleshooting Charts II and III as with other circuit sections. Some particular modes of failure and causes are:

TROUBLESHOOTING CHART II

Battery Current Consumption, Total . . . . 50 mA (Nominal)
Battery Voltage Range (Operating) 4.6 to 6.2 Volts d.c.
+6 Volt Buss Range (When +4.0 V dc is Properly set)

TRANSISTOR D. C. VOLTAGES		
Q3	E + 2.0 V Δ B + 2.8 V Δ C + 4.0 V	
Q4	E + 5.9 V B + 6.6 V C + 7.5 V	
Q5	E + 4.0 V B + 4.4 V C + 6.6 V	
Q6	E Zero B - 0.26 V C - 0.6 to -2.2 V	
Q7	E - 0.26 V B + 0.33 V C + 4.0 V	

TRANSISTOR D. C. VOLTAGES		
Q8	E + 4.0 V B + 3.4 V C + 0.33 V	
Q9	E Zero B + 0.6 V C + 0.5 V #	
Q10	E + 1.2 V # B + 0.5 V # C Zero	
Q11	E + 3.9 V # B + 3.2 V # C + 1.1 V #	
UAR2	Input +0.7 V Pin #3 +1.3 V Supply +5.5 V Output +2.8 V	Δ

Δ = Some Variation.
= This point has a large, non-symmetrical a.c. signal on it, which will measure differently on different d.c. voltmeters, therefore, the d.c. voltage given is that present when the circuit is not oscillating.

CIRCUIT POINT	D.C. VOLTAGES
Synchronous Rectifier	Positive Side +25 V ± 3 V Negative Side -25 V ± 3 V

SYMPTOM(S)	CAUSE(S)
No sensitivity to radiation	Center-tap lead, secondary, T1, touching ground at some point, or bad diode CR5 or CR6.
Low sensitivity and/or meter fallback from some indication	CR5 and/or CR6 diode(s) bad.

Some typical voltages in the Synchronous Rectifier circuit are:

CONDITION	TESTPOINT #5	TESTPOINT #6	JUNCTION OF R38 & R39	P2, PIN U
No Signal	-24 V	+24V	0 V	0 V
Full-Scale Signal	-31V	+17 V	3.5 V	-2.5 V*

*Will measure approximately -1.6 V when loaded by 10 megohm voltmeter.

Feedback Divider troubles should be fairly well limited to the malfunction of switch deck S1C or the breakage of cable conductors going to and from switch deck S1C. Connector set P2 - J2 and pins U and T are also possible sources of trouble due to contact corrosion.

4.4.6 Probe Assembly - No field maintenance should be attempted on the Probe Assembly. A special high-purity wax fills this entire assembly. The melting point of the wax is close enough to the maximum temperature rating of internal components that a carefully set laboratory oven is required for unpotting or potting.

Experience has also shown that a certain amount of wax loss and contamination are unavoidable in such operation. All high impedance circuitry is confined within the Probe Assembly and the ion chamber is an integral part of the assembly. Servicing ion chambers and high impedance circuitry demand more than the usual electronic skills. For all of these reasons, servicing of the Probe Assembly should be left to the factory. Because of the necessary delay involved in a factory repair, troubleshooting routines which indicate the trouble as being definately associated with the Probe Assembly should be carefully double-checked. Figure 25 shows connector P1 on the base of the Probe Assembly, and d.c. resistances.

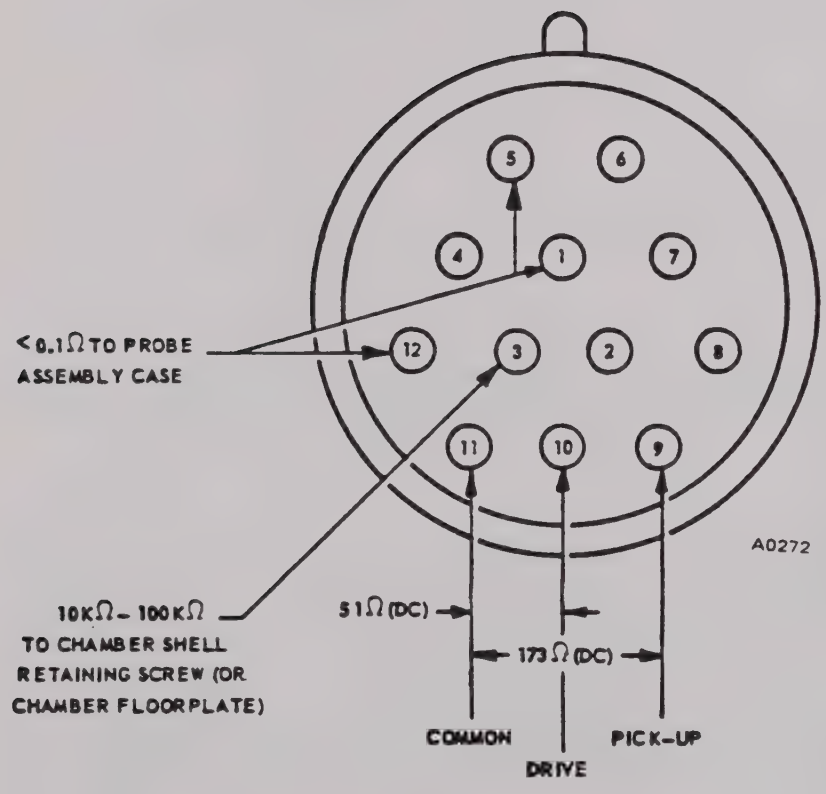
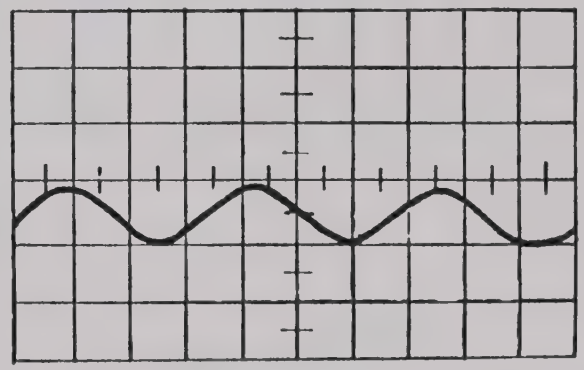


Figure 25. D. C. Resistances, Connector P1, Probe Assembly

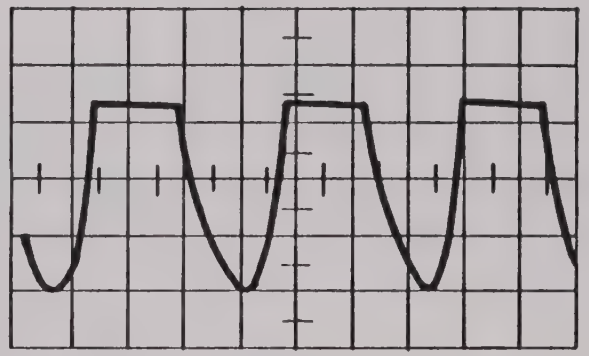
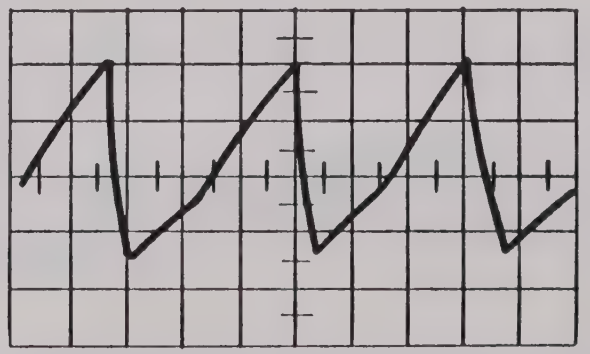
Troubleshooting Chart III lists certain key test points in the instrument and indicates what voltages and waveforms should be present at these test points in the case of the normally operating instrument. Further, the chart indicates which circuit section is likely to be malfunctioning when an abnormal indication is obtained from a test point. This chart should help find and cure troubles not covered by Chart I's symptom list.

TROUBLESHOOTING CHART III

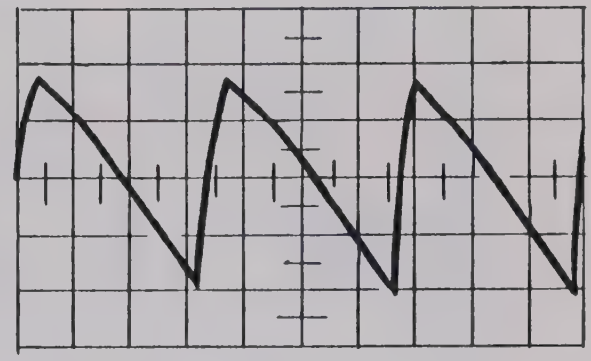
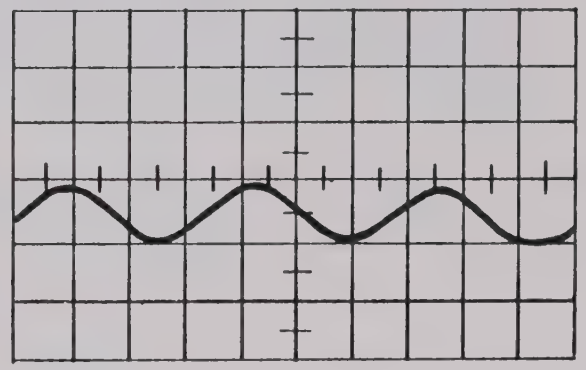
MODEL 440 RF/C			TEST EQUIPMENT		
Range	Indication	Key Test Point No. & Circuit	Equipment & Settings	Indication: Normal	Indication: If Abnormal See Section
100 mR/hr	0	#1 +4 V Regulator	d.c. Voltmeter Range selected for highest on-scale indication	+4.0 V d.c.	4.4.2
100 mR/	0	#2 +6 V Regulator	d.c. Voltmeter Range selected for highest on-scale indication	+6.0 V d.c. ±7%	4.4.2
100 mR/hr	0	#3 Pick-Up Coil	Oscilloscope Vert. Sensitivity - 100 mV/Div. Horiz. Sweep - 1 ms/Div. Trigger Polarity - Positive		4.4.3

Voltages and all waveforms are measured between the test point and ground unless otherwise noted.

TROUBLESHOOTING Chart III (Cont'd.)

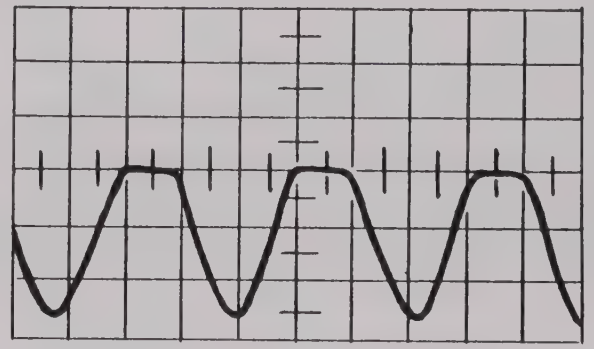
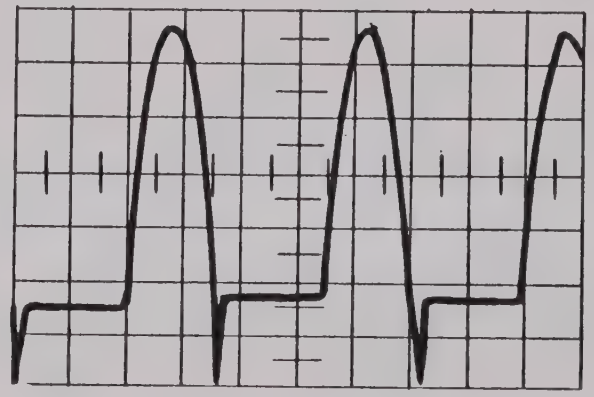
MODEL 440 RF/C			TEST EQUIPMENT		
			Equipment & Settings	Indication	
Range	Indication	Key Test Point No. & Circuit		Normal	If Abnormal See Section
100 mR/hr	0	#4 Drive Coil	Oscilloscope Vert. Sensitivity - 2V/Div. Horiz. Sweep - 1 ms/Div. Trigger Polarity - Negative		4.4.3
100 mR/ hr	0	#5 Negative Side of Synchronous Rectifier	Oscilloscope Vert. Sensitivity - 1V/Div. Horiz. Sweep - 1 ms/Div. Trigger Polarity - Negative d.c. Voltmeter	 -24V d.c. ±10%	4.4.5

TROUBLESHOOTING CHART III (Cont'd.)

MODEL 440 RF/C			TEST EQUIPMENT		
			Equipment & Settings	Indication	
Range	Indication	Key Test Point No. & Circuit		Normal	If Abnormal See Section
100 mR/ hr	0	#6 Positive Side of Synchronous Rectifier	Oscilloscope Vert. Sensitivity - 1V/Div. Horiz. Sweep - 1 ms/Div. Trigger Polarity - Positive		4.4.5
			d.c. Voltmeter	+24 V d.c. ±10%	
100 mR/hr	Full Scale	#7 Carrier Input To Circuit Board	Oscilloscope Vert. Sensitivity - 10 mV/Div. Horiz. Sweep - 1 ms/Div. Trigger Polarity - Positive		4.4.4

Voltages and all waveforms are measured between the test point and ground unless otherwise noted.

TROUBLESHOOTING CHART III (Cont'd.)

MODEL 440 RF/C			TEST EQUIPMENT		
			Equipment & Settings	Indication	
Range	Indication	Key Test Point No. & Circuit		Normal	If Abnormal See Section
100 mR/hr	Full Scale	#8 Integrated Circuit Carrier Output	Oscilloscope Vert. Sensitivity- 0.5 V/Div. Horiz. Sweep - 1 ms/Div. Trigger Polarity- Negative		4.4.4
100 mR/hr	Full Scale	#9 Carrier Output To Synchronous Rectifier	Oscilloscope Vert. Sensitivity- 0.5 V/Div. Horiz. Sweep - 1 ms/Div. Trigger Polarity- Negative		4.4.5

Voltages and all waveforms are measured between the test point and ground unless otherwise noted.

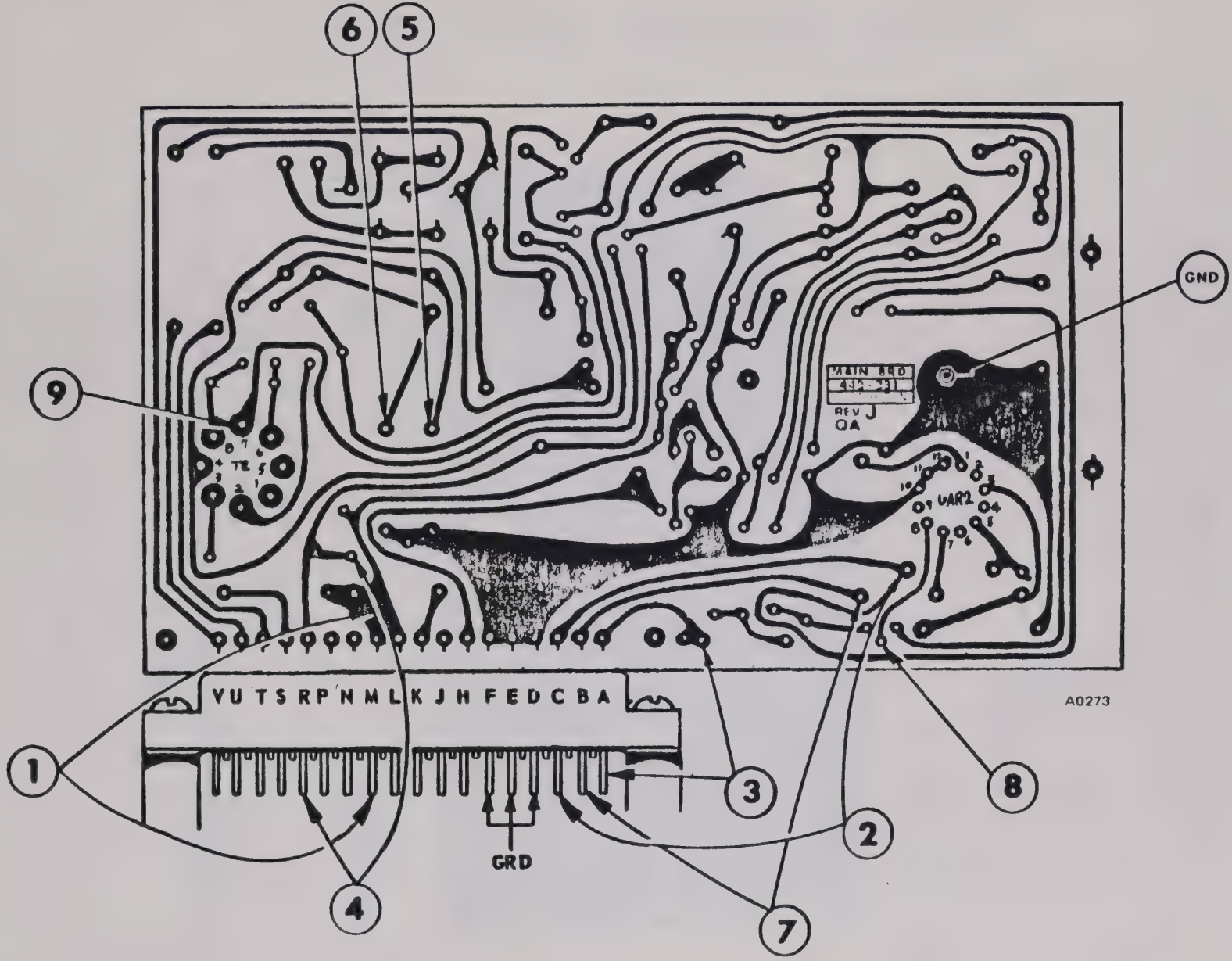


Figure 26. Test Points, Printed Circuit Board, Printed Side

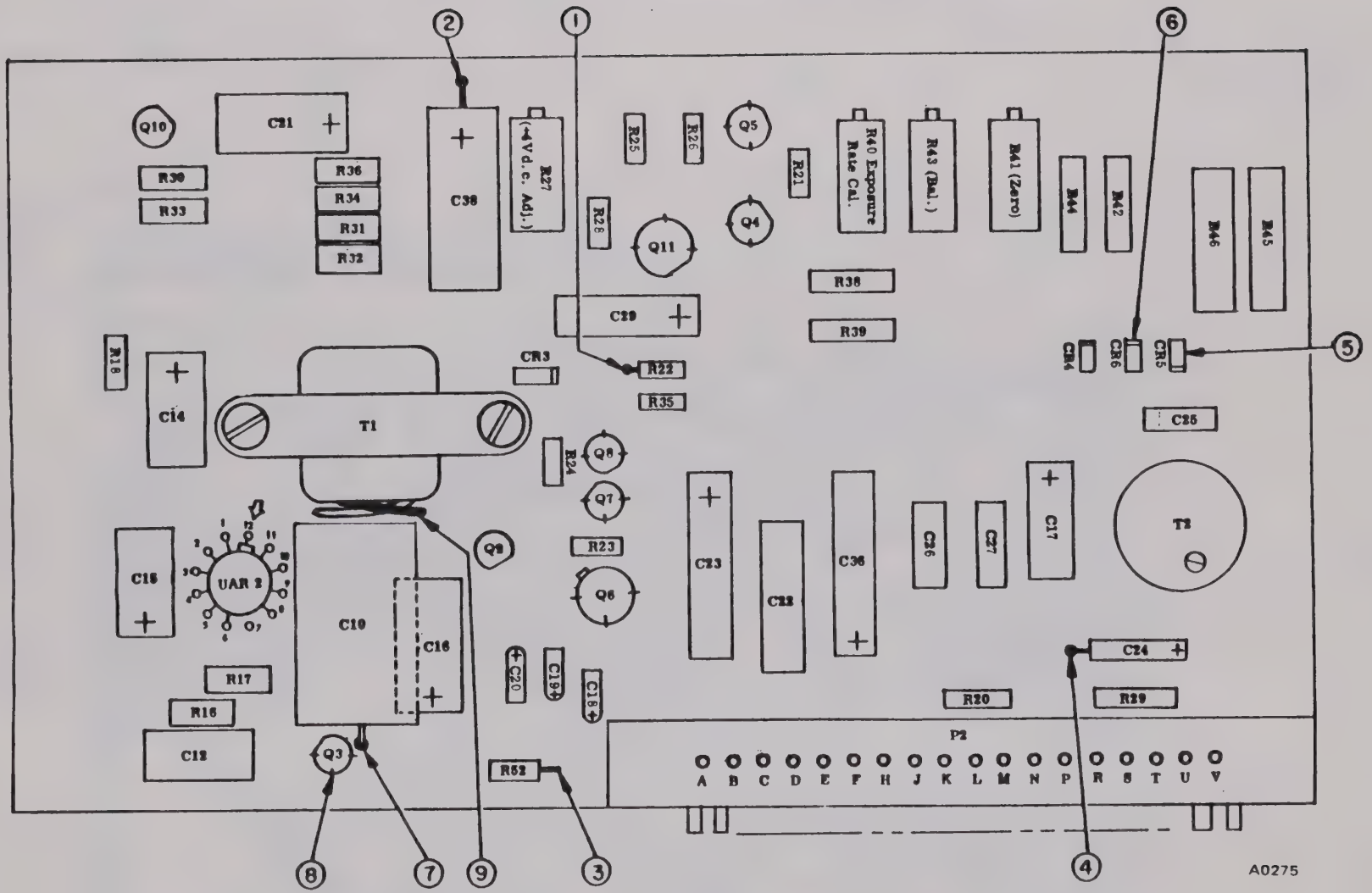


Figure 27. Test Points, Printed Circuit Board, Component Side

4.5 Electrical Adjustments

C A U T I O N

Before making any electrical adjustments of the instrument, be certain that the adjustment is required and the proper control is being adjusted.

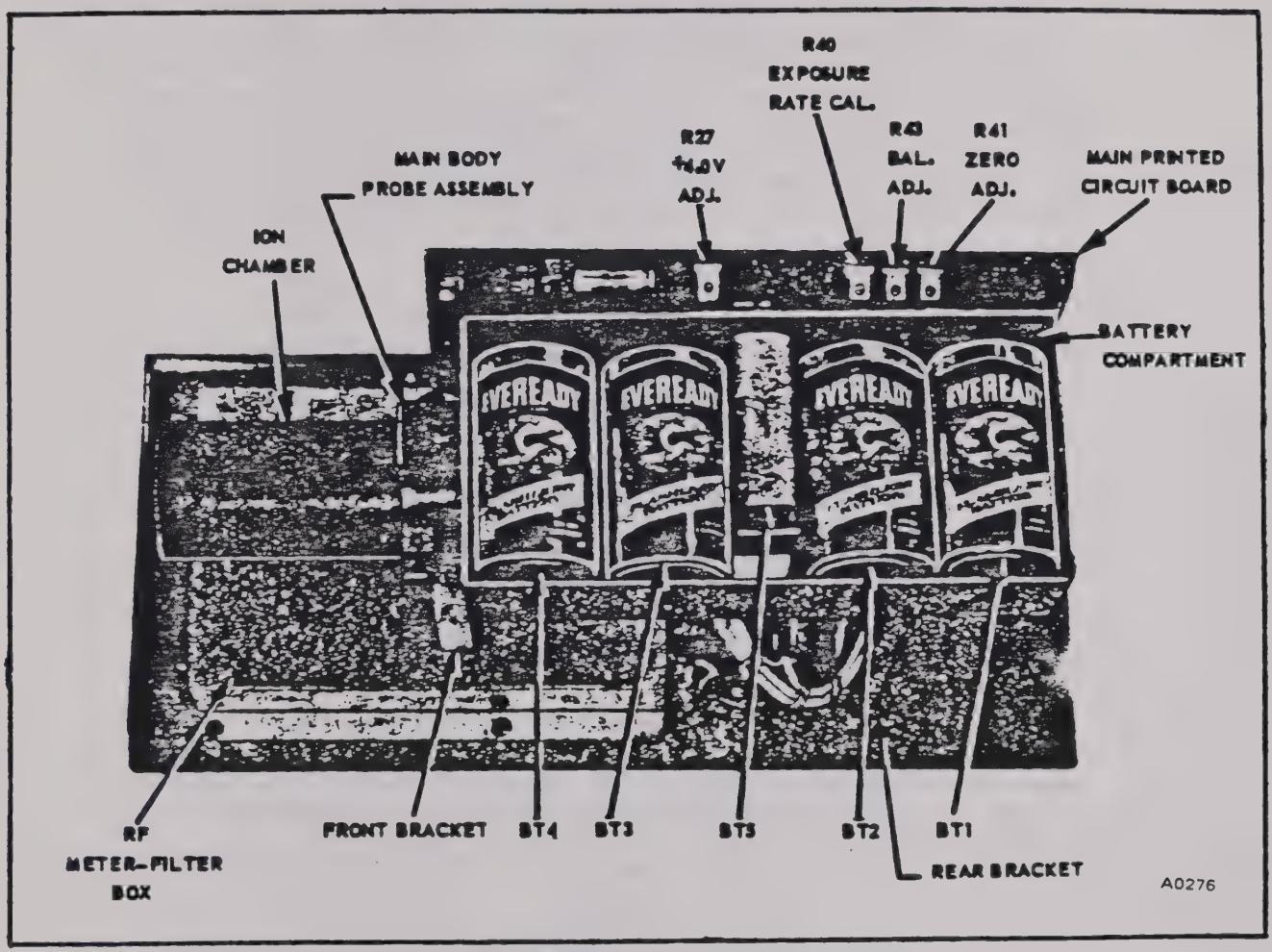


Figure 28. Case Top Assembly, Bottom View (Showing Control Locations)

See Figure 28 for control identification. If the Exposure Rate calibration control, R4, is adjusted accidently, the special low-energy factory calibration may be lost (see section 4.6.1).

4.5.1 +4.0 Volt (and +6 Volt) Regulator - +4.0 volt adjust, variable resistor R27, sets the current through the zener reference diode CR3 and thereby the +4.0 volt regulator output. The +6 volt regulator has no separate adjustment, but is referenced to the +4.0 volt regulator in such a way that when the +4.0 volt regulator is properly set, the +6 volt regulator output will be within 7% of +6.0 volts. Before making any regulator adjustment make sure that the D cells, BT1 through BT4, are good, and that the d.c. voltmeter used complies with section 4.1.

To make the adjustment:

1. Perform mechanical disassembly, 4.2.1.
2. Connect the d.c. voltmeter between P2 - J2, Pins L or M, (Test point #1).
3. Select the d.c. voltmeter range that will give the largest on-scale deflection for +4.0 volts d.c.
4. Turn the Model 440 RF/C's function switch to the Bat position and allow the instrument to run for at least five minutes.
5. See Figure 28 for correct location of the +4.0 volt adjust, R27; then with a trimpot adjustment tool or small screwdriver, vary the control until the d.c. voltmeter indicates +4.0 volts d.c.

4.5.2 Zero Adjustment and Synchronous Rectifier Balance - Because the adjustment procedures for these two controls are very similar and since their adjustment is electrically interdependent, these adjustments are grouped together in this section.

N O T E

Make certain the adjustment is required. The instrument is carefully adjusted at the factory and normally should not require adjustment. Rough handling of the instrument can sometimes cause what seems to be a constant up or down scale indication, particularly on the more sensitive ranges. Within a few hours (or sometimes as long as a day), however, the instrument should, after a severe mechanical

shock, return to its normal operation even on the most sensitive range. It is not necessary for the instrument to be operated while waiting for insulator strain-change to decay off. After a day, the adjustment may be performed if:

1. The up or down scale indication has not diminished.
2. The batteries are good.
3. There is no indication of any malfunction. If there is an upscale indication, the operator must be certain that there is no ionizing radiation present.

The following procedure will yield a true zero because the high megohm feedback reresistor is shorted out. Attempts to zero the instrument without shorting the feedback resistor may be quite frustrating and uncertain.

1. With the instrument's function switch in the OFF position for at least a minute or so, and with the instrument in the physical attitude that it is most likely to be used in, check the mechanical zero of the indicating meter. If it required adjustment, the adjustment screwhead is available through the hole on the meter case.

2. Remove the Case-Top Assembly from Case-Bottom, see section 4.2.1.

3. Remove the printed circuit board, see section 4.2.4.

4. Remove the ion chamber shell, see section 4.2.6.

5. Attach a zeroing and synchronous rectifier balance feedback network as shown below.

This network is necessary when adjusting the instrument's zero or synchronous rectifier balance because the low-pass filter effect of the current amplifier feedback resistor, R1, and input capacitance is no longer present. Merely shunting the feedback resistor without a network can cause instability and subtle oscillations which will defeat the accuracy of the adjustment.

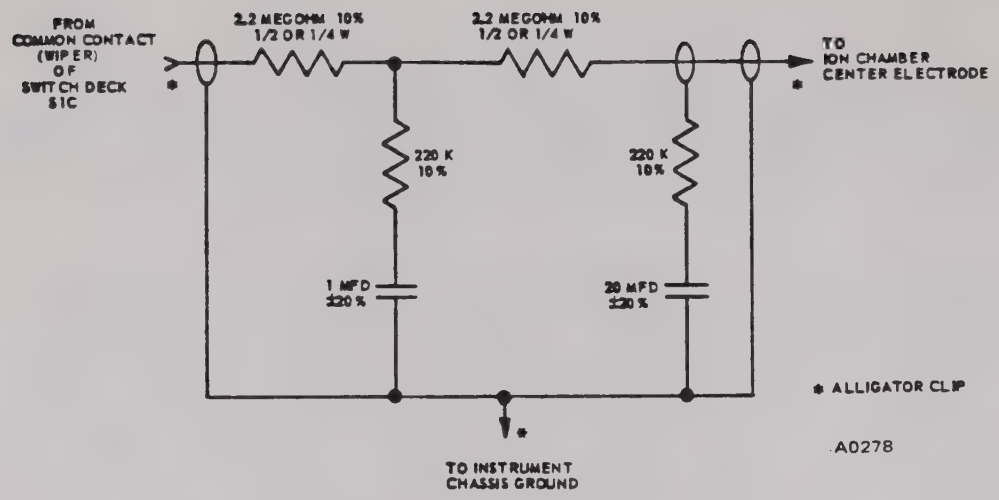

FROM COMMON CONTACT (WIPER) OF SWITCH DECK S1C
2.2 MEGOHM 10% 1/2 OR 1/4 W
2.2 MEGOHM 10% 1/2 OR 1/4 W
TO ION CHAMBER CENTER ELECTRODE
220 K 10%
220 K 10%
1 MFD ±20%
20 MFD ±20%
* ALLIGATOR CLIP
A0278
TO INSTRUMENT CHASSIS GROUND

Figure 29. Zeroing and Balance Feed-Back Network

*Paper, oil, mylar, metallized mylar or polycarbonate capacitors of any voltage rating may be used. Several units may be paralleled if necessary. Do NOT use electrolytic or tantalum capacitors.

N O T E

Try to keep the network compact and close to the instrument, or place shielding around the network. The network's impedance is high enough for the zeroing and balancing to be affected by stray a.c. fields and their harmonics being coupled into the 300 Hz carrier system.

When connecting the network to the dagged chamber center electrode, handle the electrode as little as possible and try to keep the electrode unstressed mechanically.

6. Replace printed circuit board.

7. Switch function switch to bat position. Check the batteries and let run for a few minutes.

8. Switch function switch to 100 mR/hr position.

9. Allow fifteen to twenty seconds for the indication to reach its final value.

10. If the indication is not on the meter scale zero, the Balance Adjust control, R43, should be varied until a zero indication is achieved.

C A U T I O N

Before making any electrical adjustments of the instrument, be certain that the adjustment is required and that the proper control is being adjusted. See Figure 28 for control location and identification. If the Exposure Rate Calibration control, R40 is adjusted accidently, the special low-energy factory calibration may be lost (see section 4.6.1).

11. After finding either a good zero or adjusting to one in the 100 mR/hr position, switch the function switch into the 1 mR/hr positon.

12. Allow sufficient time for a final indication, as in step (i).

13. If the indication is not on the meter scale zero, the Zero Adjust control, R41, should be varied until a zero indication is achieved.

14. If the Zero Adjust control was varied more than a full turn, it will be necessary to go back and repeat steps (h) through (m), continuing in this manner until a zero indication is available on both the 100 mR/hr and 1 mR/hr ranges. This completes the adjustment of these two controls.

15. Switch function switch to OFF.

16. Remove printed circuit board.

17. Remove feedback network.

18. Replace ion chamber shell.

19. Replace printed circuit board.

20. Replace case bottom.

4.6 Exposure Rate Calibration

N O T E

Before doubting and/or adjusting the Exposure Rate Calibration control, R40, make sure the

batteries are good, all other adjustments are properly made and any measurement correction factors, see section 2.4 and 2.8 have been applied.

4.6.1 Factory - This instrument is calibrated to a special technique. The technique consists of both a low Effective Energy and a low Exposure Rate set of conditions.

The Effective Energy and Exposure Rate are: 22 keV and 4 -6 mR/hr.

The Color Television Technique is:

X-ray Tube Voltage	27 kV Constant Potential
Inherent Filtration	1 mm Beryllium
Added Filtration	5.55 mm Aluminum +700 cm of Air
Half-Value Layer	1.1 mm Aluminum

N O T E

As this calibration technique is rather difficult, if not impossible to duplicate at most user locations, care should be taken so that the Exposure Rate Calibration control is not adjusted either accidently or arbitrarily; otherwise the special Color Television Technique calibration will be lost.

If for some reason the factory calibration is lost, two courses of action are open:

1. Factory recalibration. See Inspection and Material Return instructions in rear or this manual.

2. Field Calibration.

4.6.2 Field

N O T E

Since there must be physical access to the Exposure Rate Calibration control, R40, and since any hole in the case bottom would ren-

der the RF shielding ineffective, the first two methods of field calibration must be performed with the case bottom removed. This in turn requires a low RF as well as low background radiation location. For the last method, only a low background is required, i.e., .05 mR/hr. Always allow twice the response time as given in section 1.2 for indications to reach final values.

4.6.2.1 Method A - A known activity source may be spaced a certain distance from the center of the ion chamber volume, thus creating a known exposure rate. A correction factor may then be applied to compensate for the difference in energy responses. For example a certain activity of ^{137}Cs* is placed at a distance which causes an exposure rate of 10 mR/hr at the physical center of the ion chamber volume. The correction factor for the effective energy, 662 keV, of ^{137}Cs is 0.96. The Exposure Rate Calibration control, R40, is adjusted for an indication of 9.6 mR/hr.

(If ^{60}Co* had been used, the correction factor would have been 0.89. For other relatively monochromatic sources see Figure 9, Energy Response Correction Factor Curve, in order to determine the correction factor).

4.6.2.2 Method B - If, when the instrument was known to be in proper calibration, it was exposed to a specific source at a certain distance, and with a certain geometry and an indication obtained; then all of these conditions can be exactly repeated and the Exposure Rate Calibration control, R40, adjusted for the same indication. Note that this method does not require a direct knowledge of either the identity or activity of the source. It does presume negligible source half-life decay in the interval, however.

For future reference, a reading should be made and recorded of a specific source, at a specific distance, with specific geometrical features that can be exactly reproduced. Later when it is necessary to calibrate the instrument, the conditions can be exactly duplicated and potentiometer R40 can be adjusted to agree with the previously-recorded reading.

*When using ^{137}Cs, ^{60}Co, ^{226}Ra or other high Effective Energy isotopes (200 keV), additional equilibrium wall material must be used (see Section 2.6.1).

4.6.2.3 Method C - The internal operational check source, which is normally used for a field calibration although the procedure is somewhat slow and sumbersome.

First operate the operational check source (section 2.8) and obtain an averaged (section 2.7) indication. Compare this value with the value stamped on the case bottom place. If there is a disagreement greater than 0.1 mR/hr, the Exposure Rate Calibration control, R40, may be adjusted. Gently remove the instrument from the case bottom. When facing the adjustment screw head, counter-clockwise adjustment will cause an increased indication; clockwise, a decreased indication. Try initially a half-turn of adjustment in the direction desired. This will give some idea of how much, more or less, further adjustment may be necessary. Replace the case bottom.

N O T E

When using this method, care must be taken not to roughly handle or jar the instrument while removing or replacing the case bottom. Piezoelectric strain voltage can be generated which will take time to bleed off. This sill result in a spurious indication and make further adjustments futile without a rest period.

Operate the operational check source again to see whether or not further adjustment, and approximately how much and in which direction is necessary. Continue in this manner until good agreement is reached between the stamped plate value and the indicated value.

5 List of Replaceable Parts

5.1 Electrical Components

5.1.1 Main Printed Circuit Board

Symbol Desig.	Part No.	Description	Qty.
UAR2	63-2	Integrated Circuit: RCA CA3021	1
C10	21-647	Capacitor: .47 µF; 200 V	1
C12	21-852	Capacitor: .15 µF; 200 V	1
C14,C15,C16, C17,C21,C14, C29	21-819	Capacitor: 100 µF; 6 V	7
C18,C19,C20	21-528	Capacitor: 2.2 µF; 20 V	3
C22	21-918	Capacitor: 1 µF; 100 V	1
C23,C36,C38	21-849	Capacitor: 300 µF; 6 V	3
C25	21-851	Capacitor: .0039 µF; 80 V	1
C26,C27	21-850	Capacitor: .1 µF; 80 V	2
C28	21-848	Capacitor: .01 µF; 80 V	1
CR3	52-208	Zener Diode: IN5229B	1
CR4,CR5,CR6	52-134	Diode: IN914	3
Q3,Q4	23-66	Transistor: 2N3565	2
Q5,Q7,Q9	23-121	Transistor: EN2484	3
Q6	23-124	Transistor: 2N3428	1
Q8,Q10	23-90	Transistor: 2N4249	2
Q11	23-61	Transistor: 2N3638	1
P2	67-1	Connector: Amphenol 133-018-03	1
R16	185-20	Resistor: 100 kΩ; 1/2 W; 5%	1
R17	185-540	Resistor: 130 Ω; 1/2 W; 5%	1
R18	185-528	Resistor: 100 Ω; 1/2 W; 5%	1
R20	185-516	Resistor: 75 Ω; 1/2 W; 5%	1
R21	185-729	Resistor: 27 kΩ; 1/2 W; 5%	1
R22	185-566	Resistor: 240 Ω; 1/2 W; 5%	1
R23	185-656	Resistor: 2.2 kΩ; 1/2 W; 5%	1
R24	185-670	Resistor: 3 kΩ; 1/2 W; 5%	1
R25	185-723	Resistor: 22 kΩ; 1/2 W; 5%	1
R26	185-230	Resistor: 6.8 kΩ; 1/2 W; 5%	1
R27	22-270	Potentiometer: 2 kΩ	1
R28,R52	185-557	Resistor: 200 Ω; 1/2 W; 5%	2
R29	185-1772	Resistor: 69.8 kΩ; 1/2 W; 5%	1
R30	185-739	Resistor: 39 kΩ; 1/2 W; 5%	1

List of Replaceable Parts (Cont'd).

Symbol Desig.	Part No.	Description	Qty.
R31	185-743	Resistor: 47 kΩ; 1/2 W; 5%	1
R32	185-706	Resistor: 10 kΩ; 1/2 W; 5%	1
R33	185-584	Resistor: 390 Ω; 1/2 W; 5%	1
R34	185-609	Resistor: 580 Ω; 1/2 W; 5%	1
R35	185-1773	Resistor: 3.6 Ω; 1/2 W; 5%	1
R36	185-649	Resistor: 1.8 Ωk ; 1/2 W; 5%	1
R38,R39	185-1770	Resistor: 182 kΩ; 1/2 W; 1%	2
R40	22-301	Potentiometer: 100 kΩ	1
R41,R43	22-287	Potentiometer: 1 MΩ	2
R42,R44	185-1593	Resistor: 499 kΩ; 1/2 W; ±1%	2
R45	185-2523	Resistor: 12 MΩ; ± 1%	1
R46	185-2524	Resistor: 18 MΩ; ± 1%	1

5.1.2 Chassis

C30,C31,C32, C33,C34,C35,	21-1067	Capacitor: .001 F; 300 V	6
C37	21-849	Capacitor: 300 F; 6V	1
J2	440-374	Connector: 18-Pin Female	1
L1,L2,L3,L4	440-149	Choke: Coil; 1 mh	4
M1	440-168	Meter and Scale Assembly	1
J1	31-44	Connector: Deutsch 9700-12S	1
R11	185-2447	Resistor: 750 ; 1/4 W; ± 5%	1
R12	185-1448	Resistor: 200 ; 1/4 W; ± 5%	1
R13	185-1483	Resistor: 68 ; 1/4 W; ± 5%	1
R14	185-1450	Resistor: 20 ; 1/4 W; ± 5%	1
R15	185-2436	Resistor: 10 ; 1/4 W; ± 5%	1
R37	185-1464	Resistor: 18 k ; 1/4 W; ± 5%	1
R47	185-1769	Resistor: 30 k ; 1/2 W; 1%	1
R48	185-1768	Resistor: 120 k ; 1/2 W; 1%	1
R49	185-1767	Resistor: 422 k ; 1/2 W; 1%	1
R50	185-1612	Resistor: 1.2 M ; 1/2 W; 1%	1
R51	185-1766	Resistor: 4.22 M ; 1/2 W; 1%	1
S1A,S1B,S1C, S1D	440-393	Switch: Rotary	1

5.2 Probe Components

Symbol Desig.	Part No.	Description	Qty.
	440-371	Chamber Assembly	1
	440-372	Electrode Assembly	1
	440-350	Chamber Base	1
	440-396	Mounting Plate & Seal Assembly	1
	44-92	Washer (Special)	3
	440-431	Lead Shield	1
	185-1775	Hi-Meg 4.5 x $10^{12}\Omega$	1
	37-31	Mounting Clip Rivets	4
	185-1774	Hi-Meg 2 x $10^{9}\Omega$	1
	40-71	Spacer	1
	440-386	Pre-amp. Assembly	1
	440-353	Shield	1
	21-958	Capacitor 20 pF; 500 V; $\pm$ 5%	1
	440-347	Reed Mtg. Ring	1
	440-42	Probe Housing	1
	441-205	Dynamic Capacitor	1
	440-381	Cap Assembly	1
	29-16	Feed Thru Lug	1
	440-424	Pre-amp. Harness	1
	440-398	Insulator	1
		#4-40 x 1/2 Rnd. Hd. Nylon Screw	3
	46-7	"O" Ring	1
	440-422	Shield Plate	1

5.3 Mechanical Components

	9-33	Function and Range Knob
	9-33-5	Knob Decal
	440-136	Battery Case Clip
	440-172	Meter Case
	440-376	Battery Case
	440-397	Main Wiring Harness
	440-405B	Magnesium Window
	440-410	Plastic Bumper
	592-175	Carrying Handle

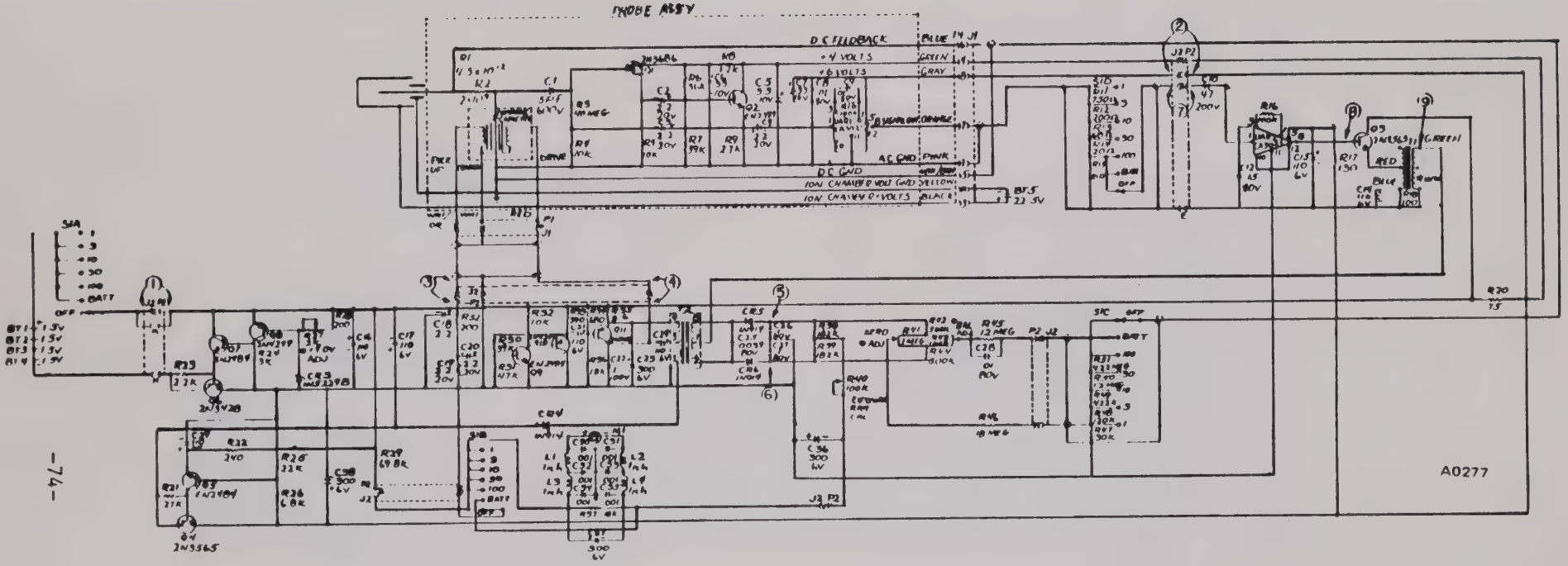
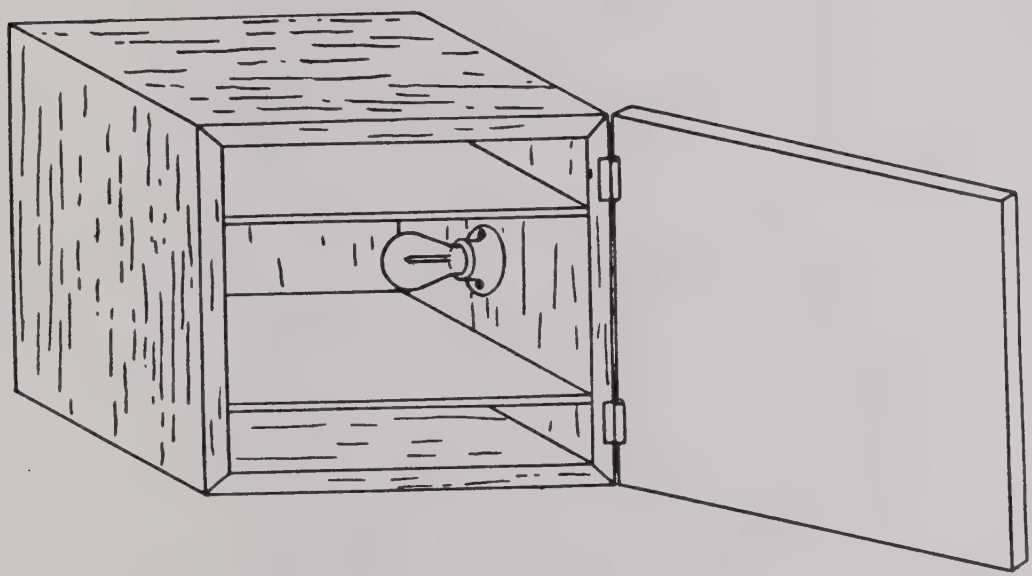


FIGURE 30. Model 440 RF/C Complete Schematic Circuit Diagram

THE PROPER CARE AND STORAGE OF ION CHAMBER INSTRUMENTS SHOULD FOLLOW THE GUIDELINES LISTED BELOW:

In areas where the humidity is exceptionally high, Ion Chamber instruments may become saturated with moisture causing then to fail. To avoid this occurance, store instruments in a typical dry box (See Illustration). Smaller instruments can be stored in polyethylene bags with dessiccant packet or a dry box with either a 100-watt light bulb or renewable dessiccant packet.



Sample dry box with light bulb and shelves.*
(wood materials used)

*NOTE: This particular dry box is an artist's presentation and not necessarily in existence. The customer may use a different type of dry box so long as it is applicable to their instruments and needs.

BP:A1

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